August 1996
Volume 41, Number 8
ISSN 0020-1324-RECACP

RESPIRATORY CARE

A MONTHLY SCIENCE JOURNAL
41ST YEAR—ESTABLISHED 1956

- Respiratory Care Assessment-Treatment Program
- Bird Avian Transport Ventilator Evaluation
- Evaluation of ServO$_2$ Oxygen-Control System
- Airway Leak during Ventilation of the Neonate
- Evaluation of 21 Passive Humidifiers
- *CRCE through the Journal—1996*

AARC

42nd International Convention & Exhibition
November 3-6 • San Diego, California

We just added the missing piece to the ventilator management picture

The New VENTRAK® combines Respiratory Mechanics and Mainstream Capnography to provide information not available on any ventilator or graphics package:

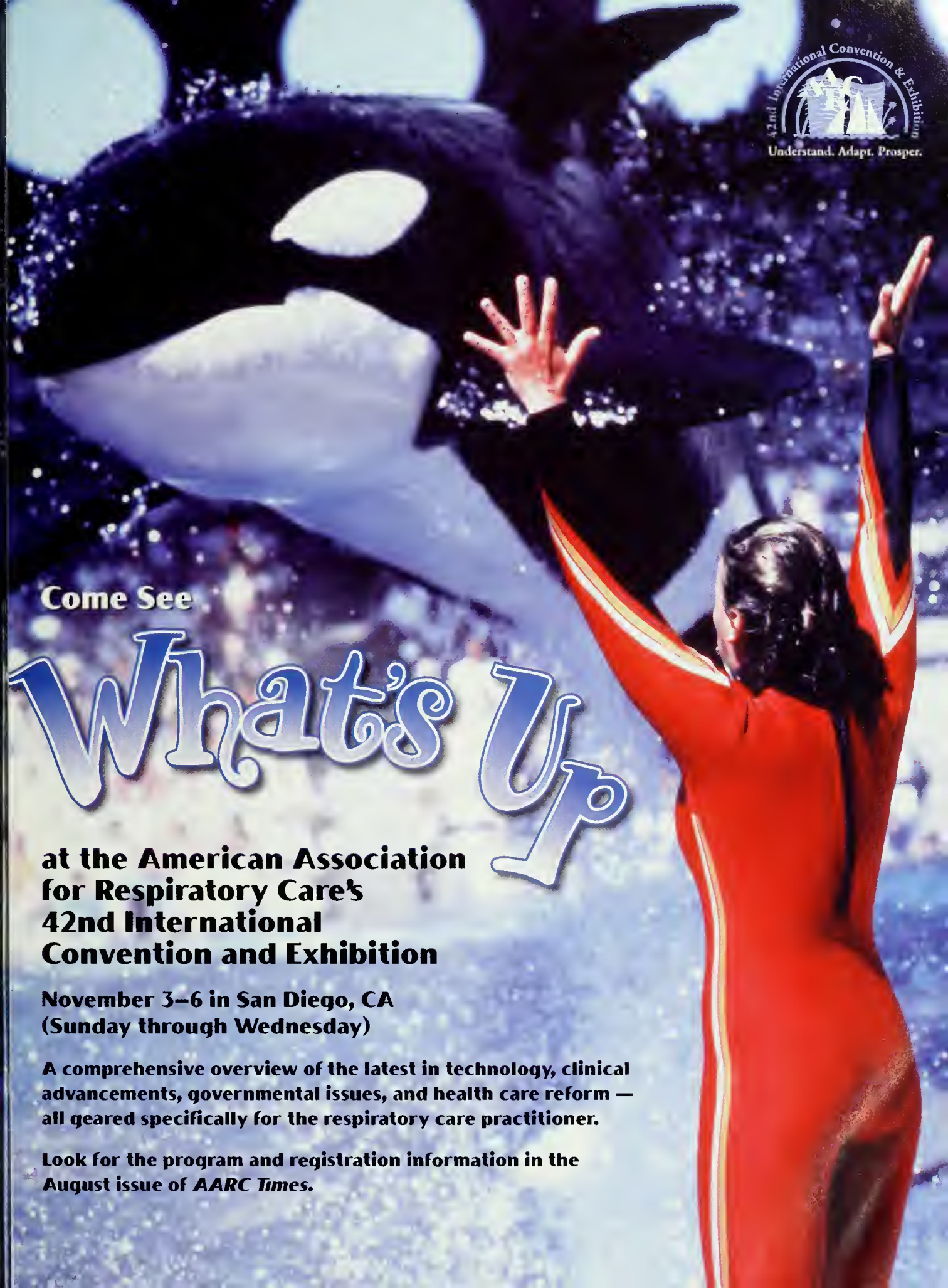
- ***Deadspace***
- ***CO_2 Production***
- ***Alveolar Ventilation***

The Novametrix VENTRAK provides the definitive view of the patient-ventilator relationship *facilitating* ***safer, faster*** and ***controlled*** *patient and ventilator management.*

To complete the ventilator management picture, call Novametrix today at 1-800-243-3444
fax: (203) 284-0753 • http://www.novametrix.com

NOVAMETRIX
MEDICAL SYSTEMS INC.

Circle 109 on reader service card


42nd International Convention & Exhibition
Understand. Adapt. Prosper.
Come See
What's Up
at the American Association for Respiratory Care's 42nd International Convention and Exhibition
November 3–6 in San Diego, CA (Sunday through Wednesday)
A comprehensive overview of the latest in technology, clinical advancements, governmental issues, and health care reform — all geared specifically for the respiratory care practitioner.
Look for the program and registration information in the August issue of AARC Times.

AARC's Professor's Rounds in Respiratory Care

EARN CONTINUING EDUCATION CREDITS

Participate in a Live Telephone Question-and-Answer Session with Videotape

(no satellite dish necessary)

OR

Watch a Live Satellite Videoconference Broadcast

(requires KU Analog or C-Band Analog satellite dish)

Clinical Focus

#1• *Management of Life-Threatening Asthma*
Tape available

#2• *Managing the Ventilator: What and When*
Tape available

#5• *Theory and Application of Neonatal Ventilation: What, When, and Why*
with Rob Chatburn, RRT, and Richard D. Branson, RRT
- Live Broadcast — August 27, 12:30 p.m. to 2:30 p.m.
- Teleconference — September 16, 12:30 p.m. to 1:00 p.m.

Supported in part by an educational grant from Hamilton Medical, Inc.

#7• *Airway Management: Tricks of the Trade*
with Charles G. Durbin, MD, and David J. Pierson, MD
- Live Broadcast — December 16, 12:30 p.m. to 2:30 p.m.
- Teleconference — December 19, 12:30 p.m. to 1:00 p.m.

Respiratory Care Issues

#3• *Managing Demand for Respiratory Care Services*
Tape available

#4• *Capturing Respiratory Services Outside the Hospital Part I: Home Care*
with Allan B. Saposnick, MS, RRT, and Sam Giordano, MBA, RRT
- Live Broadcast — July 9, 12:30 p.m. to 2:30 p.m.
- Teleconference — July 29, 12:30 p.m. to 1:00 p.m.

#6• *Capturing Respiratory Services Outside the Hospital Part II: Subacute Care*
with Kevin Cornish, RRT, and Sam Giordano, MBA, RRT
- Live Broadcast — October 15, 12:30 p.m. to 2:30 p.m.
- Teleconference — November 19, 12:30 p.m. to 1:00 p.m.

Supported in part by an educational grant from Newport Medical Instruments, Inc.

All times listed are for Eastern Time Zone.

Accreditation — Each participant completing CRCE requirements can earn one continuing education credit for each program.
Registration — Includes technical information, proctor guide, continuing education packet, certificate, and post test.

	Single Program	Seven Programs	Clinically Focused Programs	Respiratory Care Issues Programs
Nonmember	$295	$910	$685	$550
AARC Member	$260	$850	$635	$485

Live Satellite Broadcast — requires satellite reception, KU Analog or C-Band Analog capabilities, and a television monitor

Teleconference — requirements for the videotape and telephone question-and-answer session are a VHS videocassette player, a television monitor, and a telephone/speaker phone.

Videotapes — videotape-only subscribers *do not* receive continuing education credit.

Group Discounts*	1 Facility	2-25 Sites	26-50 Sites	51+ Sites
	No Discount	25%	30%	40%

*Discount is applied to each site's registration. Discount is not allowed for multiple facilities viewing at one site.

LIVE SATELLITE OR TELECONFERENCE

Registration — Please Register My Site for the Following Programs. Check the Appropriate Boxes Below:

1. ☐ Live Satellite Broadcast Registration *or* ☐ Teleconference Registration *or* ☐ Videotape Only (CE Credit Not Available)
2. ☐ Seven Programs ☐ Clinical Programs ☐ Respiratory Care Issues Programs
3. ☐ #1 ☐ #2 ☐ #3 ☐ #4 ☐ #5 ☐ #6 ☐ #7

Method of Payment ☐ Check (payable to AARC) *or* ☐ Purchase Order No. _____
or Credit Card ☐ Visa ☐ MasterCard Card Number _____

Expiration Date _____ Signature _____

Name _____ AARC Member Number _____

Institution _____

Address _____

City/State/Zip _____ Phone Number _____

Mail registration form to: **American Association for Respiratory Care, AARC Videoconferences**
11030 Ables Ln., Dallas, TX 75229-4593 • (214) 243-2272 • Fax (214) 484-2720

RESPIRATORY CARE

A Monthly Science Journal. Established 1956. Official Journal of the American Association for Respiratory Care.

EDITOR
Pat Brougher BA RRT

MANAGING EDITOR
Ray Masferrer BA RRT

EDITORIAL BOARD

James K Stoller MD, Chairman
Cleveland Clinic Foundation
Cleveland, Ohio

Richard D Branson RRT
University of Cincinnati
Medical Center
Cincinnati, Ohio

Crystal L Dunlevy EdD RRT
The Ohio State University
Columbus, Ohio

Charles G Durbin Jr MD
The University of Virginia
Health Sciences Center
Charlottesville, Virginia

Thomas D East PhD
LDS Hospital
University of Utah
Salt Lake City, Utah

Dean R Hess PhD RRT
Massachusetts General Hospital
Harvard Medical School
Boston, Massachusetts

Neil R MacIntyre Jr MD
Duke University Medical Center
Durham, North Carolina

Shelley C Mishoe PhD RRT
Medical College of Georgia
Augusta, Georgia

Joseph L Rau PhD RRT
Georgia State University
Atlanta, Georgia

Contents ...

August 1996
Volume 41, Number 8

ORIGINAL CONTRIBUTIONS

703 A Respiratory Care Assessment-Treatment Program: Results of a Retrospective Study
by Kevin L Shrake, John E Scaggs, Kevin R England, Joseph Q Henkle, Lanie E Eagleton—Springfield, Illinois

714 An Operational Evaluation of the Bird Avian Transport Ventilator
by Timothy B Op't Holt—Mobile, Alabama

724 Bench Evaluation of the ServO_2 Oxygen-Control System
by Frank Dennison, D Spencer Brudno, David Lain, Vladimir Kremenchugsky—Augusta and Marietta, Georgia and Columbia, Maryland

728 The Effect of Airway Leak on Tidal Volume during Pressure- or Flow-Controlled Ventilation of the Neonate: A Model Study
by Robert L Chatburn, Teresa A Volsko, and Mohamad El-Khatib—Cleveland, Ohio

736 Evaluation of 21 Passive Humidifiers According to the ISO 9360 Standard: Moisture Output, Dead Space, and Flow Resistance
by Richard D Branson and Kenneth Davis Jr—Cincinnati, Ohio

PULMONARY FUNCTION CORNER #53

745 Lessons from Spirometry: Look at the Picture
by Matthew Veatch, Jack Wanger, Edward Chan—Denver, Colorado

BOOKS, FILMS, TAPES, & SOFTWARE

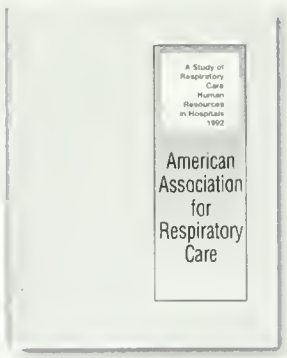
748 Clinical Assessment in Respiratory Care
reviewed by Phillip D Hoberty—Columbus, Ohio

748 Bronkie the Bronchiasaurus for the Super Nintendo Entertainment System
reviewed by Jared Knauf—The Colony, Texas

LETTERS

750 An Approach to Patient Classification
by Bruce Brown and Jeff Fraser—Melbourne, Florida
Response from Sam P Giordano—Dallas, Texas

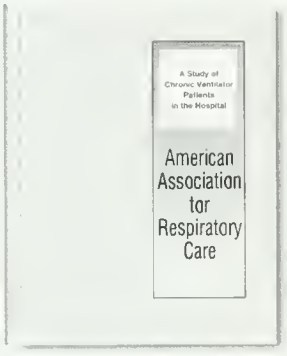
The AARC Human Resources Survey: A Study of Respiratory Care Human Resources in Hospitals



Covers a wide range of human resource issues, including compensation, numbers of full-time equivalents, job vacancy rates, education, credentialing, and licensure. Even includes information on age, sex, and years of experience. Includes comprehensive summary, position profiles, salaries, education, experience, credentials, and regional demographics. Vacancies are inventoried. 68 pages, 66 tables.

Item BK12 $35 ($50 nonmembers)

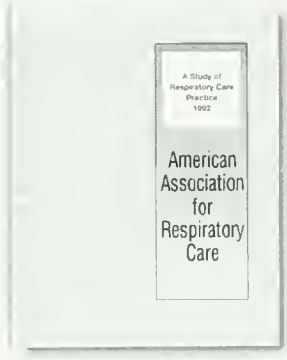
A Study of Chronic Ventilator Patients in the Hospital



Chronic ventilator-dependent patients are costing American hospitals more than $9 million per day according to this Gallup study conducted for the AARC. This important study provides information on patients who depend on life-support systems; why, how, and where they are being treated; and the cost of treatment. 47 pages, 9 tables, 12 figures.

Item BK20 $25 ($50 nonmembers)

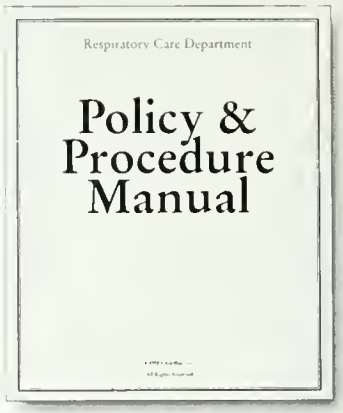
A Study of Respiratory Care Practice



This study examines the practice of respiratory care in today's health care environment and how hospital reorganization is affecting the profession. Includes chapters on medical direction, current respiratory care services, nontraditional services, respiratory care protocols, and hospital service reorganization. 38 pages, 34 tables, 15 charts.

Item BK17 $20 ($40 nonmembers)

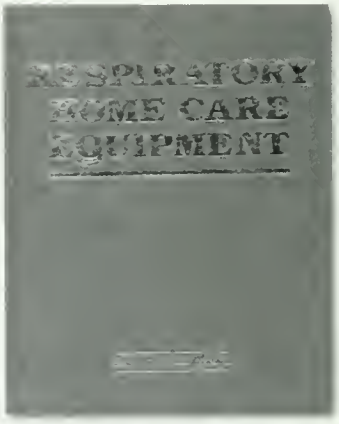
Policy and Procedure Manual



Save time and money by making your department more efficient with the *Policy and Procedure Manual*. Its 130 pages of policies and procedures cover the aspects of administrative and clinical respiratory care for both adult and pediatric practice. Sections on administrative policies, therapeutics, clinical monitoring, and mechanical ventilation. Standardized formats include objectives, indications, equipment, policies, contraindications, troubleshooting, procedures, hazards, and assessment of effectiveness.

Item BK6 $60 ($70 nonmembers)

Respiratory Home Care Equipment



Respiratory Home Care Equipment exclusively covers home care equipment with practical applications and charts on oxygen concentrators, liquid units, air compressors, and home care ventilators. An invaluable book for the home care practitioner and equipment technician. Details home care devices, cleaning, disinfecting, and monitoring procedures to minimize infection. Includes guides for educating staff on equipment, therapy, patient assessment, and safety. Features procedures for gas administration and monitoring devices, humidifiers and nebulizers, artificial airways and resuscitators, respirators, and ventilators. By Steven P. McPherson. Hardcover, 192 pages, 141 illustrations, 6 tables.

Item BK7 $9 ($12 nonmembers)

Orders with credit cards or P.O. numbers may call (214) 243-2272, or Fax to (214) 484-2720.
If ordering by mail, send coupon to:
AARC Order Department, 11030 Ables Lane, Dallas, Texas 75229-4593.

Shipping Rates* Order Total	UPS Reg.	2nd Day for AK,HI,PR	2nd Day	Next Day
$15 or less	$ 4.00	$12.00	$ 9.00	$17.00
$15.01 to $25	$ 5.00	$14.25	$11.25	$21.25
$25.01 to $40	$ 6.00	$16.50	$13.50	$25.50
$40.01 to $60	$ 7.00	$18.75	$15.75	$29.75
$60.01 to $80	$ 8.00	$21.00	$18.00	$34.00
$80.01 to $100	$10.00	$25.50	$22.50	$42.50
$100.01 to $150	$12.00	$30.00	$27.00	$51.00
$150.01 to $200	$13.00	$32.25	$29.25	$55.25
$200.01 to $250	$14.00	$38.00	$35.00	$63.00
$250.01 to $300	$16.00	$43.00	$40.00	$72.00
$300.01 and up	$18.00	$57.00	$54.00	$90.00

*orders require an additional $10 for orders up to $100, add $15 for orders over $100

Foreign orders shipped air parcel post unless otherwise expressed. AK, HI, and PR shipped 2nd day air only at rates above.

Please send me the items I have indicated below.

Item	Description	Quantity	Price Each	Total Price

Ship via UPS ☐ Regular ☐ 2nd Day Next Day
Please use the chart to the left to calculate shipping.

Shipping _____
Merchandise $ _____
TOTAL _____

☐ Check or Money Order enclosed payable to the AARC
☐ Bill me, my P.O. No. is _____
☐ Charge to my ☐ Visa ☐ MasterCard
Card # _____ Exp. Date _____ Signature × _____
AARC Member # _____ Name _____
Institution _____
Address _____ City/State/Zip _____

Texas customers only, please add 8 ¼% sales tax (including shipping charges). Texas customers that are exempt from sales tax must attach an exemption certificate

ASSISTANT EDITOR
Kris Williams BA

EDITORIAL ASSISTANT
Linda Barcus BBA

PRODUCTION COORDINATOR
Karen Singleterry BS

SECTION EDITORS
Robert R Fluck Jr MS RRT
MS Jastremski MD
Blood Gas Corner

Hugh S Mathewson MD
Drug Capsule

Richard D Branson RRT
Robert S Campbell RRT
Kittredge's Corner

Charles G Irvin PhD
Jack Wanger MBA RPFT RRT
PFT Corner

Patricia Ann Doorley MS RRT
Charles G Durbin Jr MD
Test Your Radiologic Skill

Barbara Wilson MEd RRT
Jon Meliones MD
John Palmisano RRT
Cardiorespiratory Interactions

CONSULTING EDITORS
Frank E Biondo BS RRT
Howard J Birenbaum MD
Robert L Chatburn RRT
Donald R Elton MD
Ronald B George MD
James M Hurst MD
Robert M Kacmarek PhD RRT
Michael McPeck BS RRT
David J Pierson MD
John Shigeoka MD
Jeffrey J Ward MEd RRT

PRODUCTION
Steve Bowden
Donna Knauf

MARKETING
Dale Griffiths
Director
Tim Goldsbury
Director of Advertising Sales
Beth Binkley
Advertising Assistant

EDITORIAL OFFICE
11030 Ables Lane
Dallas TX 75229
(214) 243-2272

... Contents

August 1996
Volume 41, Number 8

HISTORICAL NOTE

744 Reflecting on 40 Years of RESPIRATORY CARE: Looking Ahead
from Respir Care 1956;1(1):7-8.

CLASSIC REPRINT

752 Retrospectroscope: Publisher's Dawdle: An Incurable Disease?
by Julius H Comroe Jr (Reprinted, with permission, from Am Rev Respir Dis 1977;115:131-134.

CONTINUING EDUCATION EXAMINATION

755 CRCE through the Journal—1996

IN THIS ISSUE

686 Abstracts from Other Journals
776 Advertisers Index & Help Lines
773 Application
776 Author Index
775 Calendar of Events
768 Manuscript Preparation Guide
765 MedWatch
767 New Products & Services
772 Notices

RESPIRATORY CARE (ISSN 0020-1324) is published monthly by Daedalus Enterprises Inc, at 11030 Ables Lane, Dallas TX 75229-4593, for the American Association for Respiratory Care. One volume is published per year beginning each January. Subscription rates are $65 per year in the US; $80 in all other countries (for airmail, add $84).
The contents of the Journal are indexed in Hospital and Health Administration Index, Cumulative Index to Nursing and Allied Health Literature, and Excerpta Medica. Abridged versions of RESPIRATORY CARE are also published in Italian and Japanese, with permission from Daedalus Enterprises Inc.
Periodicals postage paid at Dallas TX. POSTMASTER: Send address changes to RESPIRATORY CARE, Membership Office, Daedalus Enterprises Inc, 11030 Ables Lane, Dallas TX 75229-4593.
Copyright © 1996, by Daedalus Enterprises Inc.

Editorials, Commentaries, and Reviews To Note

Hyperbaric-Oxygen Therapy (Review)—PM Tibbles, JS Edelsberg. N Engl J Med 1996;334(25): 1642-1648.

Treatment of Obstructive Sleep Apnea (Review)—DW Hudgel. Chest 1996;109(5):1346-1358.

Reactive Airways Dysfunction Syndrome (Review)—WM Alberts, GA do Pico. Chest 1996;109 (6):1618-1626.

The Inhalation Device Influences Lung Deposition and Bronchodilating Effect of Terbutaline—L Borgström, E Derom, E Stahl, E Wåhlin-Boll, R Pauwels. Am J Respir Crit Care Med 1996;153:1636.

The development of new inhalation devices for asthma drugs raises the issue of the relationship between pulmonary deposition and therapeutic effect of inhaled drugs in patients with obstructive lung diseases. We thus conducted a randomized, double-blind and double-dummy, 4-period crossover study in 13 patients with moderate asthma (mean age 36 years; FEV_1 59% of predicted), who inhaled 0.25 and 0.5 mg terbutaline sulphate on separate occasions either via a pressurized metered dose inhaler (pMDI) or Turbuhaler® (TBH). Pulmonary deposition was 8.1 ± 2.7% and 8.3 ± 2.3%, respectively, of the nominal dose for pMDI and 19.0 ± 7.3%, and 22.0 ± 8.1% for TBH. The FEV_1 increase after 0.25 mg terbutaline sulphate via TBH was significantly greater than after 0.25 mg via pMDI. No significant differences in FEV_1 increase were observed between 0.25 mg via TBH, 0.5 mg via pMDI, or 0.5 mg via TBH. Other lung function variables showed similar dose- and device-related changes. We concluded that: (1) the dose of terbutaline sulphate deposited in the lungs is dependent on which inhalation system is used; (2) TBH delivers about twice the amount of drug to the lungs as the pMDI; and (3) the observed difference in deposition is reflected in the bronchodilating effect.

Prevalence and Incidence of Adult Pertussis in an Urban Population—ME Nennig, HR Shinefield, KM Edwards, SB Black, BH Fireman. JAMA 1996;275(21):1672-1674

OBJECTIVES: To determine the prevalence of *Bordetella pertussis* infection among adults who have prolonged cough for 2 weeks or longer and to estimate the incidence of *B. pertussis* infection in adults in a defined urban population. DESIGN: A prospective clinical study. SETTING: Kaiser Permanente, San Francisco (CA) Medical Center. PARTICIPANTS: One hundred fifty-three referred and participating health plan members 18 years old or older with the complaint of cough persisting for 2 weeks or longer and 154 health plan members 18 years old or older with no cough for the past 3 months (controls) were enrolled. Medical records for an additional 100 patients randomly sampled from 676 patients 18 years old or older with an ambulatory diagnosis of cough (60 with prolonged cough) were also reviewed. MAIN OUTCOME MEASURES: Prevalence of adult pertussis as determined by enzyme-linked immunosorbent assay IgG antibody levels to pertussis toxin in individuals with prolonged cough for 2 weeks or longer and the incidence of adult pertussis in San Francisco Kaiser health plan members. RESULTS: The prevalence of adult pertussis was 12.4% of the participating referrals. The incidence of adult pertussis was estimated to be 176 cases per 100,000 person-years (95% confidence interval, 97 to 255 cases). CONCLUSIONS: Adult pertussis is a significantly greater public health threat than previously suspected. Booster doses of acellular pertussis vaccine after 7 years of age may be an effective approach to minimize transmission and infection.

Markers for Primary Care: Missed Opportunities to Immunize and Screen for Lead and Tuberculosis by Private Physicians Serving Large Numbers of Inner-City Medicaid-Eligible Children—G Fairbrother, S Friedman, KA DuMont, KS Lobach. Pediatrics 1996;97(6): 785-790.

OBJECTIVE: This study examines coverage levels for immunization, missed opportunities to immunize, and extent of lead and tuberculosis screening in inner-city storefront physician offices and then relates child, visit, and physician characteristics to missed opportunities. METHODOLOGY: With the use of a nested sampling strategy, 232 charts were selected for review in 31 physicians' offices. Charts selected were for children 0 to 35 months of age who had 3 or more visits in more than 3 months. Physicians were selected from those in specific low-income New York inner-city neighborhoods who submitted large volumes of Medicaid billing claims. Variables examined were missed opportunities to immunize, immunization coverage levels, lead, and tuberculosis screening. The outcome measure was missed opportunities to immunize. RESULTS: Only 26% of the children were up to date for their age for diphtheria, tetanus, pertussis (DTP), oral polio vaccine (OPV), and measles, mumps, rubella (MMR) compared with a city-wide coverage level of 49%. Children who were not up to date for immunization coverage were more likely not to be up to date for lead (RR = 1.24, CI 0.96 to 1.60) or tuberculosis (RR = 1.54, CI 1.14 to 2.08) screening. Physicians miss opportunities to immunize in 84% of the eligible visits. Opportunities to immunize are missed more frequently at sick care or follow-up visits (95% and 91% missed opportunities) than at well care visits (41% missed opportunities). CONCLUSIONS: The quality of pediatric primary care given by these inner-city storefront physicians is suboptimal. Sick and follow-up visits predominate; well care visits are infrequent. If care is to be improved, Medicaid reimbursement policies, which make delivery of well care unprofitable, will need to be changed. In addition, monitoring the quality of care will need to be more aggressive. In the near future children who receive Medicaid in New York will be in managed care. If reimbursement and monitoring policies that provide incentives for delivering pediatric primary care are to be in place, it will be the managed care plans that implement this.

The West Virginia Society for Respiratory Care
and the
American Association for Respiratory Care
present a

Special Pre-Convention Seminar

Monday, September 30, 1996 • Huntington, West Virginia

The 1996 Annual Convention of the West Virginia Society will be held Tuesday and Wednesday, October 1-2, at the Radisson Hotel in beautiful Huntington. This year's convention will be preceded by a special seminar organized in cooperation with the American Association for Respiratory Care. The seminar will present timely information on how respiratory care practitioners and their employers can change and benefit from today's hospital restructuring programs. The seminar is approved for 6 hours of continuing respiratory care education (CRCE) credit by the AARC.

For additional program information, registration form, and hotel reservation for this special seminar and the West Virginia Society annual meeting, please

write to:
The WVSRC Program and Education
P.O. Box 433
Montgomery, WV 25136

or call:
Jay Wildt RRT CPFT at (304) 442-7474
Jean Fisher RRT at (304) 357-4851

Successful Strategies for Tomorrow's Respiratory Care Services

10:00 a.m. - 10:05 a.m.
Program Overview

10:05 a.m. - 10:50 a.m.
The Needs of Health Care Systems in the Future—Emerging Trends and Expanding Skills Inventory
Presents the forces impacting on health care delivery and the response by delivery systems. Reviews past, present, and future reimbursement mechanisms and the response of delivery systems to incentives they create. Explains the impact of expanding post acute services, opportunities for RCPs, and the skill sets required to add value in future health care systems.

10:55 a.m. - 11:40 a.m.
Providing Value in Acute Care Facilities—Managing Demand for Services
Defines the value added by RCPs in present and future acute care facilities. Describes how to sell decision-makers on the value of using guidelines and protocols to ensure appropriate utilization. Defines resources and support required to implement a utilization control program. Presents a case study of a department that has been successful in ensuring appropriate utilization.

11:45 a.m. - 12:30 p.m.
The Post Acute Environment—Skilled Nursing Facilities, Subacute, and Home Care
Identifies market forces and governmental regulations that foster growth in the post acute environment. Discusses the opportunities for RCPs created by government and private managed care contracting. Reviews the mechanism for reimbursement of respiratory care services in post acute sites and the current HCFA scrutiny of transfer agreements.

1:30 p.m. - 2:25 p.m.
Respiratory Care in Group Practice and Disease Management
Explores opportunities for RCPs as mid-level providers in capitated physician group practice. Defines disease management and explains why asthma patients are ideal candidates for disease management programs. Identifies skill sets required by mid-level providers and explains why RCPs add unique value to respiratory disease management programs.

2:30 p.m. - 3:25 p.m.
Respiratory Care in the Future: Integrated Care Delivery Systems
Describes market forces encouraging the development of integrated care delivery systems. Reviews current and projected penetration of managed care across the nation. Explains the components of an integrated delivery system and the competitive advantage afforded by the system. Presents a proposed respiratory care service structure to meet the needs of an integrated care delivery system.

3:30 p.m. - 4:25 p.m.
Marketing and Selling Your Service and Your Services
Presents a systematic approach to developing new or expanded services. Discusses fundamentals of a business plan and techniques for successfully presenting ideas to organizational decision-makers. Reviews common pitfalls to avoid.

Home versus Intensive Care Pressure Support Devices: Experimental and Clinical Comparison—F Lofaso, L Brochard, T Hang, H Lorino, A Harf, D Isabey. Am J Respir Crit Care Med 1996;153:1591.

A bench study using an artificial lung model and a clinical study in patients were performed to evaluate 6 commercially available home pressure support devices. Six devices were tested in the in vitro study, including 5 designed for home use and one designed for use in intensive care units. Minimal positive end-expiratory pressure (PEEP) varied across home devices, from 0.5 cm H_2O to 4.3 cm H_2O. Work imposed during exhalation varied up to 6-fold across devices. A substantial rebreathing volume was present for the 3 home devices with a common inspiratory and expiratory line. This rebreathing volume decreased with increasing PEEP level, as expected, but remained substantial at the widely used PEEP level of 5 cm H_2O. Use of a non-rebreathing valve increased both the work imposed by the circuit during the exhalation phase and the time required to attain the relaxation equilibrium. Except for 2 home devices and a bi-level positive airway pressure (BiPAP) device equipped with a non-rebreathing valve, differences in inspiratory trigger sensitivities were small between home and intensive care devices. During pressure support, the total work performed by the machines did not differ by more than 15% between devices, whereas differences of more than 300% were observed in flow acceleration. Only 1 home device gave a flow acceleration similar to or better than that obtained with the intensive care device. In a randomized, crossover clinical study, we compared a home device to a device specially designed for intensive care use in 7 intubated patients during weaning from mechanical ventilation. The main differences between these 2 devices were trigger sensitivity and initial flow acceleration. For the same level of pressure support, there were no significant differences in arterial P_{CO_2}, tidal volume, respiratory rate, or minute ventilation between these 2 devices. However, the esophageal pressure-time product was 30% higher with the home device (165 ± 93 vs 119 ± 80 cm H_2O/min, $p < 0.05$). In conclusion, differences exist between devices in terms of occurrence of rebreathing, speed of attainment of stable pressure support level, and expiratory resistance. These differences characterizing the delivery of pressure support may have clinical impact on the inspiratory effort of patients.

Effect of Hypertonic Saline, Amiloride, and Cough on Mucociliary Clearance in Patients with Cystic Fibrosis—M Robinson, JA Regnis, DL Bailey, M King, GJ Bautovich, PTP Bye. Am J Respir Crit Care Med 1996;153:1509.

In patients with cystic fibrosis (CF), dehydration of airway secretions leads to a decrease in mucociliary clearance (MCC). We examined the acute effect on MCC of a single administration by aerosolization of hypertonic saline (7%) (HS), amiloride (0.3% in 0.12% NaCl) (AML) and a combination of AML and HS (AML + HS) in 12 patients with CF using a radioaerosol technique. Isotonic saline [0.9%] (IS) was used as a control solution. As both the AML and HS solutions induced cough in some patients, the last 9 patients studied also underwent a cough clearance day. This was to eliminate the possible confounding effect of cough on MCC measurement. Patients ranged from 18 to 28 years (mean ± SD, 22 ± 3) with an FEV_1 of 27 to 112% predicted (61 ± 30%). Following deposition of the radioaerosol, baseline clearance was assessed for 30 minutes. This was followed by a 30-minute intervention period. Assessment of post-intervention clearance for a further 30 minutes was then performed. Comparison of the amount of radioaerosol cleared from the right lung was made at 60 minutes (%C60) and 90 minutes (%C90) using repeated measures ANOVA. The percent cleared at 60 and 90 minutes was significantly increased with HS (%C60 = 26.5%, %C90 = 29.4%) and the combination of AML + HS (%C60 = 23.1%, %C90 = 27.4%) compared with both IS (%C60 = 14.7%, %C90 = 17.5%) and COUGH (%C60 = 18.0%, %C90 = 19.5%), $p < 0.01$. Inhalation of hypertonic saline is a potentially useful treatment in patients with cystic fibrosis.

Does Oxygen Help Dyspnea in Patients with Cancer?—S Booth, MJ Kelly, NP Cox, L Adams, A Guz. Am J Respir Crit Care Med 1996; 153:1515.

Dyspnea in patients with advanced cancer is a common symptom that is difficult to treat. This study investigated whether oxygen helps to relieve rest dyspnea in patients with advanced cancer. In a single-blind controlled trial, oxygen and air were administered in random order to hospice patients reporting dyspnea at rest. Measurements of arterial oxygen saturation, lung function, and dyspnea (using a visual analogue scale [VAS] and Borg score) were made before and after each gas had been given for 15 minutes. Data from 38 patients were used: analysis of variance revealed that mean VAS levels during baseline conditions, breathing room air (59 mm), were significantly reduced after administration of either air (48 mm; $p < 0.001$) or oxygen (45 mm; $p < 0.001$); there was no significant difference for the mean VAS scores between oxygen and air administration. There was no statistically significant order of treatment effect. There was no difference in the response to oxygen or air in patients with a history of cardiopulmonary disease. The improvement in dyspnea with oxygen could not be predicted from a subject's initial level of hypoxia. Results suggested that benzodiazepines may potentiate the effect of oxygen. The overall conclusion is that oxygen and air can have a significant effect in reducing dyspnea at rest in patients with advanced cancer.

Correction of Blood pH Attenuates Changes in Hemodynamics and Organ Blood Flow during Permissive Hypercapnia—VJ Cardenas Jr, JB Zwischenberger, W Tao, PJ Nguyen, T Schroeder, LD Traber, DL Traber, A Bidani. Crit Care Med 1996;24(5):827.

OBJECTIVES: To determine whether changes in cardiac output, regional blood flow, and intracranial pressure during permissive hypercapnia are blood pH-dependent and can be attenuated by correction of intravascular acidemia. DESIGN: Prospective, controlled study. SETTING: Research laboratory. SUBJECTS: Female Marino ewes. INTERVENTIONS: Animals were instrumented with a pulmonary artery catheter, femoral arterial and venous catheters, a catheter in the third cerebral ventricle, and ultrasonic flow probes on the left carotid, superior mesenteric, and left renal arteries 1 week before experimentation. At initiation of the protocol, ewes underwent endotracheal intubation and mechanical ventilation under general anesthesia. Minute ventilation was reduced to induce hypercapnia with a target P_{aCO_2}

42nd International Convention & Exhibition
SAN DIEGO
November 3-6, 1996, Sunday-Wednesday

WIN!

A Picture-Perfect Vacation to San Diego, California and the AARC Annual Meeting

San Diego, California...a picture-perfect vacation destination where you can explore the ocean depths of Sea World,® go wild at the world famous San Diego Zoo, head south of the border to Tijuana, kick back and enjoy the sun-bleached beaches of Mission Bay, and partake of the exciting AARC Annual Meeting.

To picture yourself in this exciting vacation package, circle number 84 on the reader service card in this issue, request any other material you might like to receive, complete the requested information, and mail the card.

Your picture-perfect vacation includes:

- Round-trip air transportation to San Diego for two, November 2–6, 1996
- 4 nights hotel accommodations, including room tax, at a selected San Diego hotel, November 2–5, 1996
- Admission to the AARC Annual Meeting, November 3–6, 1996 (Sunday–Wednesday)

Official Rules: No purchase necessary. To enter, circle number 84 on the reader service card in this issue, request any other material you might like to receive, then complete your name, address, telephone number, and other information requested. Mail the postage-paid card to AARC Publications, P.O. Box 11605, Riverton, NJ 08076-7205. Entries must be received no later than midnight September 1, 1996. Prize is valid for travel only November 2–6, 1996. Entrants must be at least 18 years of age. Illegible entries will be disqualified. *AARC Times* and RESPIRATORY CARE® are not responsible for late, lost, damaged, or misdirected mail. The winner will be selected in a random drawing at Daedalus Enterprises, 11030 Ables Lane, Dallas, TX 75229-4593 on or about September 5, 1996. Federal, state, and local taxes are not included in prize package. Meals, gratuities, and all other expenses not specified herein are the responsibilities of the winner. Void where prohibited by law, and all federal, state, and local laws apply. NO substitution for prizes. Prizes are not transferable and are not redeemable in cash. The winner will be notified by mail or telephone.

Circle 84 on reader service card

The South Carolina Society for Respiratory Care
and the
American Association for Respiratory Care
present a

Special Pre-Convention Seminar

Monday, September 23, 1996 • Charleston, South Carolina

The 1996 Annual Convention of the South Carolina Society will be held Tuesday through Thursday, September 24-26, at the Hilton Hotel in beautiful Charleston. This year's convention will be preceded by a special seminar organized in cooperation with the American Association for Respiratory Care. The seminar will present timely information on how respiratory care practitioners and their employers can change and benefit from today's hospital restructuring programs. The seminar is approved for 6 hours of continuing respiratory care education (CRCE) credit by the AARC.

Successful Strategies for Tomorrow's Respiratory Care Services

9:00 a.m. - 9:05 a.m.
Program Overview

9:05 a.m. - 9:55 a.m.
The Needs of Health Care Systems in the Future—Emerging Trends and Expanding Skills Inventory presents the forces impacting on health care delivery and the response by delivery systems. Reviews past, present, and future reimbursement mechanisms and the response of delivery systems to incentives they create. Explains the impact of expanding post acute services, opportunities for RCPs, and the skill sets required to add value in future health care systems.

10:00 a.m. - 10:55 a.m.
Providing Value in Acute Care Facilities—Managing Demand for Services defines the value added by RCPs in present and future acute care facilities. Describes how to sell decision-makers on the value of using guidelines and protocols to ensure appropriate utilization. Defines resources and support required to implement a utilization control program. Presents a case study of a department that has been successful in ensuring appropriate utilization.

11:00 a.m. - 11:55 a.m.
The Post Acute Environment—Skilled Nursing Facilities, Subacute, and Home Care identifies market forces and governmental regulations that foster growth in the post acute environment. Discusses the opportunities for RCPs created by government and private managed care contracting. Reviews the mechanism for reimbursement of respiratory care services in post acute sites and the current HCFA scrutiny of transfer agreements.

1:30 p.m. - 2:25 p.m.
Respiratory Care in Group Practice and Disease Management explores opportunities for RCPs as mid-level providers in capitated physician group practice. Defines disease management and explains why asthma patients are ideal candidates for disease management programs. Identifies skill sets required by mid-level providers and explains why RCPs add unique value to respiratory disease management programs.

2:30 p.m. - 3:25 p.m.
Respiratory Care in the Future: Integrated Care Delivery Systems describes market forces encouraging the development of integrated care delivery systems. Reviews current and projected penetration of managed care across the nation. Explains the components of an integrated delivery system and the competitive advantage afforded by the system. Presents a proposed respiratory care service structure to meet the needs of an integrated care delivery system.

3:30 p.m. - 4:25 p.m.
Marketing and Selling Your Service and Your Services presents a systematic approach to developing new or expanded services. Discusses fundamentals of a business plan and techniques for successfully presenting ideas to organizational decision-makers. Reviews common pitfalls to avoid.

For additional program information, registration form, and hotel reservation for this special seminar and the South Carolina Society annual meeting, please

write to:
SCSRC, P.O. Box 21801
Columbia, SC 29220-1801

or call:
Trish Blakely RRT at (803) 771-5405
Laura Lucas RRT at (803) 771-5535

of 80 torr (10.7 kPa). In the pH-uncorrected group (n = 6), arterial blood pH was allowed to decrease without treatment. In the pH-corrected group (n = 5), 1.4.4 mEq/kg of sodium bicarbonate was given intravenously as a bolus to correct arterial blood pH toward a target arterial pH of 7.40 (dose calculated by the Henderson-Hasselbalch equation). MEASUREMENTS & MAIN RESULTS: Arterial blood pH, P_{CO_2}, cardiac output, intracranial pressure, and carotid, superior mesenteric, and renal artery blood flow rates were measured at normocapnic baseline and at every hour during hypercapnia for 6 hours. In the pH-uncorrected group, arterial blood pH decreased from 7.41 ± 0.03 at normocapnia to 7.14 ± 0.01 ($p < 0.01$ vs normocapnia) as blood P_{CO_2} increased to 81.2 ± 1.8 torr (10.8 ± 0.2 kPa). In the pH-corrected group, arterial blood pH was 7.42 ± 0.02 at normocapnia and was maintained at 7.37 ± 0.01 while P_{aCO_2} was increased to 80.3 ± 0.9 torr (10.7 ± 0.1 kPa). Significant increases in cardiac output occurred with the initiation of hypercapnia for both groups (pH-uncorrected group: 4.3 ± 0.6 L/min at normocapnia vs 6.8 ± 1.0 L/min at 1 hour [$p < 0.05$]; pH-corrected group: 4.1 ± 0.4 at normocapnia vs 5.7 ± 0.4 L/min at 1 hour [$p < 0.05$]). However, this increase was sustained only in the uncorrected group. Changes in carotid and mesenteric artery blood flow rates, as a percent of baseline values, showed sustained significant increases in the pH uncorrected groups ($p < 0.05$) and only transient (carotid at 1 hour) or no (superior mesenteric) significant change in the pH-corrected groups. Conversely, significant increases in renal artery blood flow were seen only in the pH-uncorrected group during the last 2 hours of the experiment ($p < 0.05$). Organ blood flow, as a percent of cardiac output, did not change significantly in either group. Intracranial pressure increased significantly in the pH-uncorrected group (9.0 ± 1.5 mm Hg at normocapnia vs 26.8 ± 5.1 at 1 hour, $p < 0.05$), and remained increased, while showing no significant change in the pH-corrected group (8.5 ± 1.6 mm Hg at normocapnia to 7.7 ± 4.2 at 1 hour). CONCLUSIONS: Acute hypercapnia, induced within 1 hour, is associated with significant increases in cardiac output, organ blood flow, and intracranial pressure. These changes can be significantly attenuated by correction of blood pH with the administration of sodium bicarbonate, without adverse effects on hemodynamics.

Liquid Assisted Ventilation: An Alternative Ventilatory Strategy for Acute Meconium Aspiration Injury—R Foust III, NN Tran, C Cox, TF Miller Jr, JS Greenspan, MR Wolfson, TH Shaffer. Pediatr Pulmonol 1996;21:316.

Evidence of surfactant inactivation by meconium has led to the use of exogenous surfactant therapy in the management of meconium aspiration syndrome (MAS). Liquid assisted ventilation has been shown to improve the cardiopulmonary function in lungs with high surface tension. We compared exogenous surfactant therapy with liquid assisted ventilation in the management of experimental acute meconium aspiration injury. Thirty-two newborn lambs were ventilated at peak inspiratory pressures of 13-16 cm H_2O, positive end-expiratory pressure of 3-4 cm H_2O, fractional inspired oxygen concentration (F_{IO_2}) of 1.0, and a respiratory frequency range between 30 and 35

Don't miss the

Open Forum

at the

1996 International

Convention & Exhibition

of the

American Association

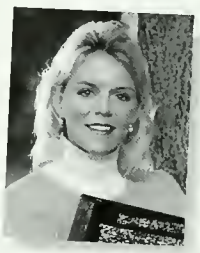
for Respiratory Care

San Diego, California

Nov. 3-6

Advance Your Health Care Career!

Earn Your Degree at Home!



Achieve Success Through Distance Education!
Get the educational credentials you need to advance your career — without spending extra time and money attending an on-campus university. Choose from California College for Health Sciences' exciting line-up of Associate's, Bachelor's, and Master's Degree Programs. You'll enjoy the benefits that come with respected credentials in any one of 10 fast growing health care specialties.

- Accredited member, Distance Education and Training Council.
- You can receive credit for work experience or previous college-level education.

CC65

CALL OR SEND FOR FREE INFORMATION!
1-800-221-7374 Ext. 438
http://www.cchs.edu
No obligation. Act today!

Call today or send this coupon to:

CCHS

Dept. 438, 222 West 24th St
National City, CA 91950
FAX #: (619) 477-4360
cchsinfo@cchs.edu

YES! I want to find out more about earning my degree at home with California College for Health Sciences

Choose one of the following Degree Programs:

Associate of Science Degree Programs
☐ Respiratory Technician ☐ Respiratory Therapist
☐ EEG Technologist ☐ Medical Transcriptionist
☐ Early Childhood Education ☐ Allied Health

Bachelor of Science in Health Services Degree Programs
☐ Emphasis in Respiratory Care
☐ Emphasis in Polysomnography
☐ Emphasis in Management

Master's Degree Program
☐ Community Health Administration and Wellness Promotion

Name _____
Address _____ Apt # _____
City/State _____ Zip _____
Phone ( ) _____ E-mail address _____
Hospital Facility _____ Phone ( ) _____

Circle 99 on reader service card

breaths/min. Baseline arterial blood gases, pulmonary function, and arterial blood pressure measurements were taken. All lambs were given 2-3 mL/kg of an unfiltered 25% meconium solution. Lambs were then randomized into either gas-ventilated meconium control, or 1 of 3 treatment groups: (1) surfactant; (2) partial liquid ventilation (PLV); or (3) total liquid ventilation (TLV) for 4 hours after meconium injury. All treated groups demonstrated a significant increase in arterial oxygenation ($p < 0.05$); surfactant and PLV-treated lambs demonstrated significantly decreased arterial P_{CO_2} ($p < 0.05$). Compliance in all groups increased compared with injury values; compliance of the TLV group increased more than in all other treatment groups ($p < 0.05$). In addition, lung histology of the TLV group demonstrated clear, intact alveolar epithelium and homogeneously expanded alveoli, while no such improvement was evident in the other groups. These data suggest roles for both exogenous surfactant therapy and liquid assisted ventilation techniques in the management of MAS.

Accuracy and Reliability of Disposable Pressure Transducers Coupled with Modern Pressure Monitors—RM Gardner. Crit Care Med 1996;24(5):879.

OBJECTIVE: To determine the bedside accuracy of direct patient pressure monitoring when used with new and clinically used disposable blood pressure (BP) transducers. DESIGN: Prospective study. SETTING: Laboratory bench and critical care units in an adult and children's hospital. SUBJECTS: Seventy-five bedside patient monitors (25 Marquette Electronics, 25 SpaceLabs Medical, and 25 Hewlett-Packard), and 100 disposable transducers (50 from Utah Medical Products and 50 from Abbott Critical Care Systems [25 new, 25 clinically used of each manufacturer]) were tested. INTERVENTIONS: None. MEASUREMENTS & MAIN RESULTS: A ±2% accuracy requirement for bedside monitors and the ±3% American National Standards Institute accuracy standard for disposable BP transducers were used. To test the accuracy of the bedside monitors, a certified transducer simulator was used to apply 100 mm Hg to each bedside monitor. To test the accuracy of the disposable BP transducers, a very accurate (±0.05%) pneumatic dead weight tester was used to apply pressures to the transducer. A digital power supply and a 6 1/2 digit voltmeter were used. The average output of the bedside monitors when 100 mm Hg was applied was 99.90 ± 0.83 mm Hg, with the worst cases being 98 and 103 mm Hg. For all 100 disposable pressure transducers, the average output was 100.03 ± 0.55 mm Hg, with the worst cases being 98.53 and 101.36 when 100 mm Hg was applied. There was no important difference in the accuracy of the transducers obtained from the 2 vendors nor whether the transducers had been used clinically. CONCLUSIONS: All disposable BP transducers tested were much more accurate than the American National Standards Institute standard for accuracy. Even the worst case transducers were twice as accurate as required by the American National Standards Institute standard. Only 1 bedside monitor was outside the ± 2% accuracy range (103 mm Hg). Based on these findings, this author recommends that fixed calibration disposable transducers and fixed calibration bedside pressure monitoring systems be used. The clinical risks of air embolism and infection from the calibrating mercury manometer and the complexity of the calibration task are the overriding factors for making these recommendations.

Which Groups of Patients Benefit from Helicopter Evacuation?—R Hotvedt, IS Kristiansen, OH Førde, J Thoner, SM Almdahl, G Bjørsvik, L Berge, AC Magnus, K Mamen, T Sparr, K Ytre-Arne. Lancet 1996;347:1362.

BACKGROUND: The evacuation of emergency cases by air, usually by helicopter, is controversial because of the cost of the programme, the possibility of an accident (especially in an urban area), and unproven benefit. But such evacuations cannot be studied by a random intervention (eg, air versus ground ambulance). We used an expert-panel approach to estimate the health outcome for patients transferred by emergency helicopter compared with the potential outcome if they had gone by surface ambulance. METHODS: The helicopter programme is based at the University Hospital of Tromso in northern Norway. 370 case-reports of helicopter evacuation from rural areas were screened by anaesthetists for routine and case-specific data. Two expert panels assessed the cases for potential additional health benefit arising from the fact of helicopter evacuation. The panels used a modified Delphi technique to reach consensus in life-years gained. One panel met for cases aged under 15 and pregnant women, the other for older cases. FINDINGS: 240 of the 370 cases were male (65%); the age range for both sexes was 0-86 years. The most common diagnosis for the 55 cases aged under 15 was infection (49%); in older patients, cardiovascular disease dominated (50%). Trauma accounted for just under a fifth of cases in both groups. On average, the patients arrived 69 minutes (range 0-615) earlier in hospital than if they had gone by ground transport. For 283 cases, the initial screening by the anaesthetists indicated no additional benefit compared with that obtainable by ground-ambulance transport. The main reason was that no treatment was given during the flight or early on in hospital that could not have been given otherwise. 90 cases entered the expert panel system. Of these 90, 49 cases were judged to have received no additional benefit. This left 41 (11% of the total of 370 evacuated) who were judged to have benefited, gaining 290.6 life years. 96% of the total number of life-years gained was achieved in 9 patients, 6 of whom were aged below 7 (4 were aged 0-7 months). The life-year-gain per adult patient with cardiovascular disease was 0.54. INTERPRETATION: We conclude that an emergency helicopter service can provide considerable health benefits for selected patients, at least in this rural setting. Given the costs and risks of such a service, the benefits for most patients are small. *See the related editorial:* ***Air Ambulances: Missions of Mercy or Flights of Futility****. CD Naylor, BA McLellan. Lancet 1996;347: 1348-1349.*

Cardiopulmonary Resuscitation on Television: Miracles and Misinformation—SJ Diem, JD Lantos, JA Tulsky. N Engl J Med 1996;334 (24):1578.

BACKGROUND: Responsible, shared decision making on the part of physicians and patients about the potential use of cardiopulmonary resuscitation (CPR) requires patients who are educated about the procedures risks and benefits. Television is an important source of information about CPR for patients. We analyzed how 3 popular television programs depict CPR. METHODS: We watched all the episodes of the television programs *ER* and *Chicago Hope* during the 1994-1995 viewing season and 50 consecutive episodes of *Rescue 911* broadcast over a 3-month period in 1995. We identified all occurrences of CPR in each episode and recorded the causes of cardiac arrest, the identifiable demographic characteristics of the patients, the underlying illnesses, and the outcomes. RESULTS: There were 60 occurrences of CPR in the 97 television episodes—31 on *ER*, 11 on *Chicago Hope*, and 18 on *Rescue 911*. In the majority of cases, cardiac arrest was caused by trauma; only 28% were due to primary cardiac causes. Sixty-five percent of the cardiac arrests occurred in children, teenagers, or young adults. Seventy-five percent of the patients survived the immediate arrest, and 67% appeared to have survived to hospital discharge. CONCLUSIONS: The survival rates in our study are significantly higher than the most optimistic survival rates in the medical literature, and the portrayal of CPR on television may lead the viewing public to have an unrealistic impression of CPR and its chances for success. Physicians discussing the use of CPR with patients and families should be aware of the images of CPR depicted on television and the misperceptions these images may foster. *See the related editorial:* ***Cardiopulmonary Resuscitation on Television: Exaggerations and Accusations****. NA Baer. N Engl J Med 1996;334(24):1604-1605.*

Psychological Impact of Population-Based Carrier Testing for Cystic Fibrosis: 3-Year Follow-Up—D Axworthy, DJH Brock, M Bobrow, TM Marteau, for the UK Cystic Fibrosis Follow-up Study Group. Lancet 1996;347:1443.

BACKGROUND: The objective of this study was to show the long-term psychological effects of population-based screening for cystic fibrosis. METH-

Celebrate RC Week

October 6-12

Promote respiratory health and the profession by informing your facility and community that there is no substitute for healthy lungs and your respiratory care practitioner. Look for RC Week advertisements and products to help you find a multitude of new, colorful, fun-filled, information-packed ways to celebrate!

ODS: The sample comprised all carriers (n = 435) and, for each carrier, 2 matched screen-negative individuals (n = 870) detected during screening programmes for cystic fibrosis in the general population and in antenatal populations carried out a median of 3 years earlier in 6 UK centres. Questionnaires were sent to all eligible participants, with reminders sent to nonresponders. The main endpoints were understanding of test results, degree of anxiety, perceptions of health, and reproductive intentions, and behaviour. FINDINGS: 746 (62%) of 1201 questionnaires were returned. Recall of the meaning of test results was accurate in 225 (80%) of 280 carriers but only 200 (43%) of 466 screen-negative individuals. 46 (16%) of 280 proven carriers believed that their result meant that they were only likely, rather than definitely, to be a carrier; 232 (50%) of 466 of those with a screen-negative result erroneously believed that the result meant that they were definitely not carriers. There was no significant difference between carriers and screen-negative individuals in degree of general anxiety, although 16% of carriers reported feeling worried about their test results. Carriers had a poorer perception of their current health than did noncarriers, even though they had been told that carrier status confers no disadvantages to their own health. There were no differences between carriers and screen-negative individuals in reproductive intentions or behaviour. INTERPRETATION: We have shown that in the long-term, retention of the meaning of test results from cystic fibrosis screening is poor. Further research is needed to improve the performance of test-related counseling programmes to ensure that the main objectives of these programmes, to provide information on carrier status and to allow informed reproductive decisions, are met.

Closed-Loop Control of Airway Occlusion Pressure at 0.1 Second ($P_{0.1}$) Applied to Pressure-Support Ventilation: Algorithm and Application in Intubated Patients—GA Iotti, JX Brunner, A Braschi, T Laubscher, MC Olivei, A Palo, C Galbusera, A Comelli. Crit Care Med 1996;24(5):771.

OBJECTIVE: Airway occlusion pressure at 0.1 second ($P_{0.1}$) is an index of respiratory center output. During pressure-support ventilation, $P_{0.1}$ correlates with the mechanical output of the inspiratory muscles and has an inverse relationship with the amount of pressure-support ventilation. Based on these observations, we designed a closed-loop control which, by automatically adjusting pressure-support ventilation, stabilizes $P_{0.1}$, and hence patient inspiratory activity, at a desired target. The purpose of the study was to demonstrate the feasibility of the method, rather than its efficacy or even its influence on patient outcome. DESIGN: Prospective, randomized trial. SETTING: A general intensive care unit of a university hospital in Italy. PATIENTS: Eight stable patients intubated and ventilated with pressure-support ventilation for acute respiratory failure. INTERVENTIONS: Patients were transiently connected to a computer-controlled ventilator on which the algorithm for closed-loop control was implemented. The closed-loop control was based on breath by breath measurement of $P_{0.1}$ and on comparison with a target set by the user. When actual $P_{0.1}$ proved to be higher than the target value, the $P_{0.1}$ controller automatically increased pressure-support ventilation, and decreased it when $P_{0.1}$ proved to be lower than the target value. For safety, a volume controller was also implemented. Four $P_{0.1}$ targets (1.5, 2.5, 3.5, and 4.5 cm H_2O) were applied at random for 15 minutes each. MEASUREMENTS & MAIN RESULTS: The closed-loop algorithm was able to control $P_{0.1}$, with a difference from the set targets of 0.59 ± 0.27 (SD) cm H_2O. CONCLUSIONS: The study shows that $P_{0.1}$ can be automatically controlled by pressure-support ventilation adjustments with a computer. Inspiratory activity can thus be stabilized at a level prescribed by the physician.

Measurement of Lung Function in Awake 2–4-Year-Old Asthmatic Children during Methacholine Challenge and Acute Asthma: A Comparison of the Impulse Oscillation Technique, the Interrupter Technique, and Transcutaneous Measurement of Oxygen versus Whole-Body Plethysmography—B Klug, H Bisgaard. Pediatr Pulmonol 1996;21:290.

This study evaluated 3 techniques for testing of lung function in young awake children. We compared measurements by the forced or impulse oscillation technique (IOS), the interrupter technique (IT), and transcutaneous measurements of oxygen (tcP_{O_2}) with concomitant measurements of specific airway resistance (sR_{aw}) during methacholine challenge in 20 stable asthmatic children, 2–4 years old. Measurements were performed with all techniques after each dose of methacholine and after inhalation of a bronchodilator. Measurements were carried out during tidal breathing using a face-mask with a built-in mouthpiece. The ranking of sensitivity was as follows: sR_{aw} > IOS, respiratory reactance at 5 Hz (Xrs5) > tcP_{O_2} > interrupter resistance (Rint) > IOS, respiratory resistance at 5 Hz (Rrs5). The sensitivity of sR_{aw} and Xrs5 was not significantly different, but both

The 1995 bound volume of RESPIRATORY CARE is now available.

Volume 40 is bound in a blue-buckram cover and may be imprinted, free of charge, with your name or the name of your organization. Each volume is $40 for current AARC members and $80 for nonmembers. Shipping is included for U.S. and Canadian residents.

Available for a limited time, the 1988 - 1991 bound volumes are discounted to $30 (members) and $70 (nonmembers). The 1992 and 1993 bound volumes are available for $35 (members) and $75 (nonmembers).

Orders must be prepaid; include check, institutional purchase order, or valid credit card number.

❑ 1995 volume at $40/$80 ❑ 1991 volume at $30/$70
❑ 1994 volume at $40/$80 ❑ 1990 volume at $30/$70
❑ 1993 volume at $35/$75 ❑ 1989 volume at $30/$70
❑ 1992 volume at $35/$75 ❑ 1988 volume at $30/$70

❑ Check ❑ Purchase Order ❑ Visa ❑ Mastercard

C.C. or P.O. # _____ Exp.date _____
Signature _____
AARC Member # _____
Name _____
Institution _____
Address _____
City _____ State _____ Zip _____
Name to imprint _____

Daedalus Enterprises Inc • PO Box 29686 • Dallas TX 75229
FAX (214) 484-6010

A

B

Puff, the Tragic Dragon
Smoking: If you think it's cool,
it's only your imagination.
American Association for Respiratory Care

C

SACCHARIN
Diet Coke
There is no substitute
for your Respiratory Care Practitioner
AMERICAN ASSOCIATION FOR RESPIRATORY CARE
11030 ABLES LANE • DALLAS, TEXAS 75229-4593 • (214) 243-2272 • FAX (214) 484 2720

Children's T-Shirt

A Your "Cool Cat" will love to wear the "Cool Cats Don't Smoke" logo on this 50/50 blend white T-shirt. Sizes small (2-4), medium (6-8), large (10-12), and extra large (14-16) available.

Item R54 $8.50 ($11.50 nonmembers)

Dragon T-Shirt

B Bright colors and a play on words to promote no smoking make this a fun shirt to wear. Available in 50/50 white cotton/polyester blend, sizes medium, large, extra large, and extra-extra large.

Item R49 $10 ($15 nonmembers)
Add $2.50 for extra-extra large.

1996 RC Week Poster

C "There is no substitute for your respiratory care practitioner." Make a statement with this 18" by 24" attention-grabbing poster.

Item R15 $4 ($8 nonmembers)

To order by credit card or purchase order, call the RC Week Hotline at (214) 406-4684.

Celebrate RC Week

October 6–12

To order by credit card or purchase order, call the RC Week Hotline at (214) 406-4684.

1996 RC Week T-Shirt

Sport this bright-colored T-shirt design, which proclaims that there is no substitute for your expertise as an RCP. Available in 50/50 white cotton/polyester blend, sizes medium, large, extra large, and extra-extra large.

Item R16 $9.75 ($11.50 nonmembers)
Add $2.50 for extra-extra large.

1996 RC Week Sweatshirt

There is no substitute for your respiratory care practitioner or this heavyweight, 50/50 blend teal sweatshirt (left) with colorful embroidered logo (above). Medium, large, extra large, and extra-extra large available.

Item R19 $25 ($30 nonmembers)
Add $2.50 for extra-extra large.

1996 RC Week Cap

Complete your RC Week ensemble with this black and teal cap. Matches both the RC Week T-shirt and sweatshirt. One size fits all.

Item R17 $6.50 ($9 nonmembers)

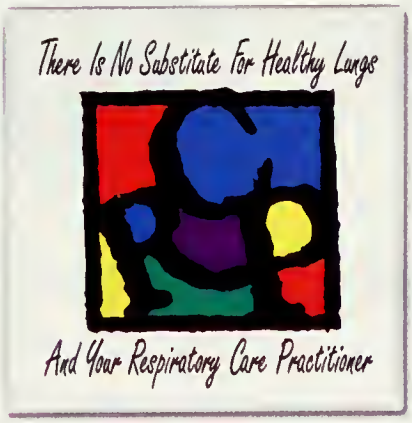
AARC

A

B

C

D



Display Banner

A Put the finishing touch on your RC Week display with this striking black banner with bright red, green, yellow, and blue. 1' by 8'.

Item R4 $11 ($15 nonmembers)

Balloons

B Bright, primary colors display a new message that promotes both smoking cessation and the respiratory care profession. Package of 100 9" round latex.

Item R1 $11 ($13.50 nonmembers)

Foil Balloons

C Bright colors display your RC Week message on these 18" silver mylar balloons. Package of 3.

Item R2 $5 ($10 nonmembers)

For safety's sake, do not release foil balloons near power lines.

RCP Buttons

D These buttons make great giveaways for your RC Week celebration. Package of 20. Safety-back pin.

Item R88 $8 ($12 nonmembers)

were significantly more sensitive than Rint and Rrs5; the sensitivity of tcP_{O_2}, Rint, and Rrs5 was not significantly different. Measurements in 8 of the subjects performed during an episode of acute asthma yielded comparable results in regard to the sensitivity of the techniques. Measurements improved significantly after bronchodilator administration; however, the response to bronchodilator tended to be less during acute asthma and was best demonstrated by a deterioration of tcP_{O_2}. All the evaluated techniques reliably reflect short-term changes in respiratory function and can provide clinically useful estimates of airway function. The techniques are noninvasive, are not dependent on the active cooperation or sedation of the subjects, and therefore are well suited for routine use in young children.

Hand-Held Blood Gas Analyzer Is Accurate in the Critical Care Setting—GP Zaloga, PR Roberts, K Black, JT Santamauro, E Klase, M Suleiman. Crit Care Med 1996;24(6):957-962.

OBJECTIVE: To determine the accuracy of a new, portable, battery-powered blood gas analyzer when used by nonlaboratory-trained clinicians in the critical care setting. DESIGN: Prospective analysis of blood samples from critically ill patients. SETTING: Large tertiary critical care unit. PATIENTS: Heterogeneous group of medical and surgical critically ill patients. INTERVENTIONS: None. MEASUREMENTS & MAIN RESULTS: Two hundred thirty-nine split blood samples from intensive care patients were analyzed by clinicians in the critical care environment using a new, portable, battery-powered blood gas analyzer (Immediate Response Mobile Analyzer [IRMA™], Diametrics Medical, St Paul MN). Near-patient measurements were compared with measurements obtained by laboratory technologists using an IL-1312 blood gas analyzer (Instrumentation Laboratories, Lexington MA) in an established near-patient critical care laboratory. Precision and coefficients of variation were also determined using repeated testing of quality control samples at 3 levels of pH, P_{O_2}, and P_{CO_2}. There was good agreement between IRMA determinations and the laboratory. Correlation coefficients ranged from 0.96 to 0.99. Bias and precision (± 2 SD), respectively, were 0.02 and 0.036 units for pH, −0.3 torr (−0.04 kPa) and 7.2 torr (0.96 kPa) for P_{CO_2}, and −3.9 torr (−0.52 kPa) and 13.8 torr (1.8 kPa) for P_{O_2}. Precision on repeated testing of quality control samples ranged from 0.022 to 0.04 units for a pH of 7.2 to 7.6, 1.2 to 4.6 torr (0.16 to 0.61 kPa) for a P_{CO_2} of 20 to 60 torr (2.7 to 8 kPa), and 3.0 to 7.4 torr (0.40 to 0.99 kPa) for a P_{O_2} of 70 to 160 torr (9.3 to 21.3 kPa). Coefficients of variation ranged from 0.15% to 0.28% for a pH of 7.2 to 7.6, 2.0% to 3.7% for a P_{CO_2} of 20 to 60 torr (2.7 to 8.0 kPa), and 1.7% to 3.6% for a P_{O_2} of 70 to 160 torr (9.3 to 21.3 kPa). Mean turnaround time was 16.5 ± 10.1 minutes for the near-patient laboratory and 2 ± 0.5 minutes for IRMA. CONCLUSIONS: IRMA is accurate and reproducible when used in the clinical setting by nonlaboratory-trained individuals. Nonlaboratory-trained individuals can obtain laboratory results in the critical care setting comparable with the results obtained by trained laboratory technologists. Bedside laboratory testing decreases turnaround time compared with a near-patient laboratory.

Breathing Measurement Reduces False-Negative Classification of Tachypneic Preextubation Trial Failures—CB DeHaven, OC Kirton, JP Morgan, AML Hart, DV Shatz, JM Civetta. Crit Care Med 1996;24(6):976-980.

OBJECTIVES: There is increased awareness of imposed work of breathing contributing to apparent ventilatory dependency. This study evaluates the impact of tachypnea as an indicator of ventilatory failure during a room air-5 cm H_2O continuous positive airway pressure, spontaneous breathing, preextubation trial when associated with increased imposed work of breathing. DESIGN: Prospective, descriptive, 1-year data collection. SETTING: University hospital trauma intensive care unit (ICU). PATIENTS: Mechanically ventilated trauma ICU patients surviving to discharge. INTERVENTION: Patients were weaned to minimal mechanical ventilator support and underwent a 20-minute room air-continuous positive airway pressure preextubation trial (F_{IO_2} = 0.21, continuous positive airway pressure = 5 cm H_2O [0.5 kPa]). When passed ($P_{aO_2} \geq 55$ torr [≥7.3 kPa], $P_{aCO_2} \leq 45$ torr [≤ 6.0 kPa] with prior eucapnea, arterial pH ≥ 7.35, respiratory rate ≤ 30 breaths/min), extubation followed. If patients failed due to hypoxemia, ventilatory support resumed. If tachypnea was the reason for failure, work of breathing was measured. If patient work of breathing was ≤ 1.1 joule/L, extubation proceeded despite tachypnea. If patient work of breathing was > 1.1 joule/L, imposed work of breathing was measured, and if residual "physiologic" work of breathing (patient work of breathing minus imposed work of breathing) was ≤ 0.8 joule/L, patients were extubated. MEASUREMENTS & MAIN RESULTS: Of 589 extubations, 105 (18%) were classified as false negatives based on a preextubation rate of > 30 breaths/min. Of these, 97 were successfully extubated despite tachypnea ranging from 32 to 56 breaths/min, when combined with either a patient work of breathing ≤ 1.1 joule/L or physiologic work of breathing ≤ 0.8 joule/L. The rate of extubation failure within 72 hours was 7.8% (8/105) in the tachypneic group, compared with 7.9% (38/484) for those patients with a respiratory rate of ≤ 30 breaths/min. Some of the stimulus for the tachypnea was possibly due to increased

Keep abreast of the latest research in RESPIRATORY CARE!

Subscribe Today!

Make checks payable to RESPIRATORY CARE (see page 776 for rates), and mail to the subscription office at 11030 Ables Lane, Dallas, Texas 75229-4593.

Clinical Practice Guidelines

AARC Clinical Practice Guidelines (CPGs) are systematically developed statements to help RCPs deliver appropriate respiratory care in specific clinical circumstances.

$1 each ($2 nonmembers)

Order all 46 CPGs in a Binder and Save!
Item CPG99 $35 ($60 nonmembers)

Topics Include:

Spirometry, 1996 Update ..... **Item CPG1**
Oxygen Therapy in the Acute Care Hospital ... **Item CPG2**
Nasotracheal Suctioning ..... **Item CPG3**
Patient-Ventilator System Checks ..... **Item CPG4**
Directed Cough ..... **Item CPG5**
In-Vitro pH and Blood Gas Analysis and Hemoximetry ..... **Item CPG6**
Use of Positive Airway Pressure Adjuncts to Bronchial Hygiene Therapy ..... **Item CPG7**
Sampling for Arterial Blood Gas Analysis ... **Item CPG8**
Endotracheal Suctioning of Mechanically Ventilated Adults and Children with Artificial Airways ..... **Item CPG9**
Incentive Spirometry ..... **Item CPG10**
Postural Drainage Therapy ..... **Item CPG11**
Bronchial Provocation ..... **Item CPG12**
Selection of Aerosol Delivery Device ..... **Item CPG13**
Pulse Oximetry ..... **Item CPG14**
Single-Breath Carbon Monoxide Diffusing Capacity ..... **Item CPG15**
Oxygen Therapy in the Home or Extended Care Facility ..... **Item CPG16**
Exercise Testing for Evaluation of Hypoxemia and/or Desaturation ..... **Item CPG 17**
Humidification during Mechanical Ventilation ..... **Item CPG18**
Transport of the Mechanically Ventilated Patient ..... **Item CPG19**
Resuscitation in Acute Care Hospitals ..... **Item CPG20**
Bland Aerosol Administration ..... **Item CPG21**
Fiberoptic Bronchoscopy Assisting ..... **Item CPG22**
Intermittent Positive Pressure Breathing ... **Item CPG23**
Application of CPAP to Neonates via Nasal Prongs or Nasopharyngeal Tube ..... **Item CPG24**
Delivery of Aerosols to the Upper Airway ... **Item CPG25**
Neonatal Time-Triggered, Pressure-Limited, Time-Cycled Mechanical Ventilation ..... **Item CPG26**
Static Lung Volumes ..... **Item CPG27**
Surfactant Replacement Therapy ..... **Item CPG28**
Ventilator Circuit Changes ..... **Item CPG29**
Metabolic Measurement using Indirect Calorimetry during Mechanical Ventilation ..... **Item CPG30**
Transcutaneous Blood Gas Monitoring for Neonatal & Pediatric Patients ..... **Item CPG31**
Body Plethysmography ..... **Item CPG32**
Capillary Blood Gas Sampling for Neonatal & Pediatric Patients ..... **Item CPG33**
Defibrillation during Resuscitation ..... **Item CPG34**
Infant/Toddler Pulmonary Function Tests ... **Item CPG35**
Management of Airway Emergencies ..... **Item CPG36**
Assessing Response to Bronchodilator Therapy at Point of Care ..... **Item CPG37**
Discharge Planning for the Respiratory Care Patient ..... **Item CPG38**
Long-Term Invasive Mechanical Ventilation in the Home ..... **Item CPG39**
Capnography/Capnometry during Mechanical Ventilation ..... **Item CPG40**
Selection of an Aerosol Delivery Device for Neonatal and Pediatric Patients ..... **Item CPG41**
Polysomnography ..... **Item CPG42**
Selection of an Oxygen Delivery Device for Neonatal and Pediatric Patients ..... **Item CPG43**
Selection of a Device for Delivery of Aerosol to the Lung Parenchyma ..... **Item CPG44**
Training the Health-Care Professional for the Role of Patient and Caregiver Educator ..... **Item CPG45**
Providing Patient and Caregiver Training ..... **Item CPG46**

Protocols

These protocols come from AARC members; they are for information purposes only, to use as a guide in developing your own.

$5 each ($8 nonmembers)

Topics Include:

Critical Care ..... **Item PC1**
Aerosol Therapy ..... **Item PC2**
Non-Invasive Monitoring ..... **Item PC3**
Volume Expansion ..... **Item PC4**
Patient Assessment ..... **Item PC5**
Oxygen Therapy ..... **Item PC6**
Secretion Management ..... **Item PC7**

Critical Pathways

Examples of multidisciplinary critical pathways have been submitted by AARC members and are available for your informational purposes and review.

Item PC30 $5 ($8 nonmembers)

Mail to: AARC, 11030 Ables Ln, Dallas TX 75229-4593 • (214) 243-2272 • FAX (214) 484-2720 or 484-6010

imposed work of breathing, as the increased respiratory rate usually abated within 18 hours after extubation. The reliance on a respiratory rate of ≤ 30 breaths/min as an absolute preextubation criterion would have resulted in a sensitivity of 82%, a specificity of 17%, a positive predictive value of 92%, a negative predictive value of 8%, and an overall accuracy of 77%. The average duration of mechanical ventilation during the study period decreased by 2 days, from 8.6 to 6.3 days ($p = 0.03$). CONCLUSIONS: Tachypnea as a marker of respiratory distress is sensitive, but is not sufficiently specific to be used as a criterion in preextubation trials. Reliance on tachypnea as a preextubation trial failure criterion is likely to prolong intubation and ventilatory support for a large number of patients. Patient risks, determined by the extubation failures and reintubation rate, are the same.

Myocardial Dysfunction after Successful Resuscitation from Cardiac Arrest—RJ Gazmuri, MH Weil, J Bisera, W Tang, M Fukui, D McKee. Crit Care Med 1996;24(6):992-1000.

OBJECTIVE: To investigate the functional and metabolic changes in the myocardium after successful resuscitation from cardiac arrest. DESIGN: Prospective, randomized, sham-controlled study. SETTING: Animal laboratory at a university center. SUBJECTS: Domestic pigs. INTERVENTIONS: Electric induction of ventricular fibrillation by alternating current delivered to the right ventricular endocardium through a pacing electrode. Electric defibrillation was attempted after an interval of 12 minutes of ventricular fibrillation, which included 4 minutes of untreated ventricular fibrillation and 8 minutes of precordial compression in 13 animals, 7 of which were successfully resuscitated. Seven additional animals were randomized to serve as "sham" controls, in which cardiac arrest was not induced. MEASUREMENTS & MAIN RESULTS: Left ventricular pressure-volume relationships utilizing the conductance method were obtained in conjunction with conventional hemodynamic and metabolic measurements at baseline and during a 6-hour interval after successful cardiac resuscitation. Progressive and striking increases in left ventricular volumes were observed after successful cardiac resuscitation. The end-diastolic volume increased from a prearrest level of 89 ± 21 mL to a maximum of 154 ± 53 mL ($p < 0.05$) at 360 minutes after successful resuscitation. The time-coincident end-systolic volume increased from 54 ± 21 to 126 ± 54 mL ($p < 0.05$), such that the ejection fraction was reduced from 0.41 ± 0.10 to 0.20 ± 0.07 ($p < 0.05$). Ventricular dilation was associated with marked reductions in stroke volume and ventricular work. However, compensatory increases in heart rate maintained cardiac output at levels that sustained adequate systemic oxygen delivery. The slope of the end-systolic pressure-volume relationships progressively decreased from 5.04 ± 1.88 to 2.00 ± 0.57 mm Hg/mL ($p < 0.05$) at 360 minutes after successful resuscitation. The volume intercept at left ventricular pressure of 100 mm Hg increased from 43 ± 19 to 94 ± 51 mL ($p = 0.03$). Both the decrease in the slope and the increase in the volume intercept were characteristic of progressive impairment in contractile function. The rate of left ventricular pressure decrease was unchanged. Accordingly, no substantial changes in lusitropic properties were identified. Despite large increases in end-diastolic volume, the end-diastolic pressure remained unchanged. CONCLUSION: Postresuscitation myocardial dysfunction in this animal model was characterized by impaired contractile function, decreased work capability, and ventricular dilation.

Evaluation of Gas Exchange, Pulmonary Compliance, and Lung Injury during Total and Partial Liquid Ventilation in the Acute Respiratory Distress Syndrome— RB Hirschl, R Tooley, A Parent, K Johnson, RH Bartlett. Crit Care Med 1996;24(6):1001-1008.

OBJECTIVE: To investigate whether pulmonary compliance and gas exchange will be sustained during "total" perfluorocarbon liquid ventilation followed by "partial" perfluorocarbon liquid ventilation when compared with gas ventilation in the setting of the acute respiratory distress syndrome (ARDS). STUDY DESIGN: A prospective, controlled, laboratory study. SETTING: A university research laboratory. SUBJECTS: Ten sheep, weighing 12.7 to 25.0 kg. INTERVENTIONS: Lung injury was induced in 10 young sheep, utilizing a right atrial injection of 0.07 mL/kg of oleic acid followed by saline pulmonary lavage. Bijugular venovenous extracorporeal life support access, a pulmonary artery catheter, and a carotid artery catheter were placed. When the alveolar-arterial O_2 gradient was ≥ 600 torr and P_{aO_2} ≤ 50 torr (≤ 6.7 kPa) with an F_{IO_2} of 1.0, extracorporeal life support was instituted. For the first 30 minutes on extracorporeal life support, all animals were ventilated with gas. Animals were then ventilated with equal tidal volumes of 15 mL/kg during gas ventilation (n = 5) over the ensuing 2.5 hours, or with total liquid ventilation for 1 hour, followed by partial liquid ventilation for 1.5 hours (total/partial liquid ventilation, n = 5). MEASUREMENTS & MAIN RESULTS: An increase in physiologic shunt (gas ventilation = 69 ± 11%, total/partial liquid ventilation = 71 ± 3%) and a decrease in static total pulmonary compliance measured at 20 mL/kg inflation volume (gas ventilation = 0.48 ± 0.03 mL/cm H_2O/kg, total/partial liquid ventilation = 0.50 ± 0.17 mL/cm H_2O/kg) were observed in both groups with induction of lung injury. Physiologic shunt was significantly reduced during total and partial liquid ventilation when compared with physiologic shunt observed in the gas ventilation animals (gas ventilation = 93 ± 8%, total liquid ventilation = 45 ± 11%, $p < 0.001$; gas ventilation = 95 ± 3%, partial liquid ventilation = 61 ± 12%, $p < 0.001$), while static compliance was significantly increased in the total, but not the partial liquid ventilated animals when compared with the gas ventilated group (gas ventilation = 0.43 ± 0.03 mL/cm H_2O/kg, total liquid ventilation = 1.13 ± 0.18 mL/cm H_2O/kg, $p < 0.001$; gas ventilation = 0.41 ± 0.02 mL/cm H_2O/kg, partial liquid ventilation = 0.47 ± 0.08, $p = 0.151$). In addition, the extracorporeal life support flow rate required to maintain adequate oxygenation was significantly lower in the total/partial liquid ventilation group when compared with that of the gas ventilation group (gas ventilation = 89 ± 7 mL/kg/min, total liquid ventilation = 22 ± 10 mL/kg/min, $p < 0.001$; gas ventilation = 91 ± 12 mL/kg/min, partial liquid ventilation = 41 ± 11 mL/kg/min, $p < 0.001$). Lung biopsy light microscopy demonstrated a marked reduction in alveolar hemorrhage, lung fluid accumulation, and inflammatory infiltration in the total/partial liquid ventilation animals when compared with the gas ventilation animals. CONCLUSIONS: In a model of severe ARDS, pulmonary gas exchange is improved during total followed by partial liquid ventilation. Pulmonary compliance is improved during total, but not during partial liquid ventilation. Total followed by partial liquid ventilation was associated with a reduction in alveolar hemorrhage, pulmonary edema, and lung inflammatory infiltration.

Surfactant Replacement in the Treatment of Sepsis-Induced Adult Respiratory Distress Syndrome in Pigs—GF Nieman, LA Gatto, AM Paskanik, B Yang, R Fluck, A Picone. Crit Care Med 1996;24(6):1025-1033.

OBJECTIVE: To evaluate the efficacy of treating sepsis-induced adult respiratory distress syndrome (ARDS) by instillation of exogenous surfactant in a porcine endotoxin model. DESIGN: Prospective trial. SETTING: Laboratory at a university medical center. SUBJECTS: Fifteen hybrid pigs, weighing 15 to 20 kg. INTERVENTIONS: Pigs were anesthetized and surgically prepared for hemodynamic and lung function measurements. Animals were randomized into 3 groups: a control group (group I; n = 4) that received sham *Escherichia coli* lipopolysaccharide (endotoxin); an endotoxin group (group II: n = 6) that received endotoxin (25 μg/ kg); and an endotoxin + surfactant (Infasurf, ONY, Amherst NY) instillation group (group III; n = 5) that received endotoxin (25 μg/kg) followed by surfactant (100 mg/kg) instillation; all groups were studied for 6 hours after the start of endotoxin injection. At necropsy, lung water and surfactant function (Wilhelmy balance) were measured and the right middle lung lobe was fixed for histologic analysis. Surfactant function was expressed as the surface tension at the minimum trough area. MEASUREMENTS & MAIN RESULTS: Surfactant treatment (group III) significantly ($p < 0.05$) decreased venous admixture (group III = 41.5 ± 9.1%; group II =

61.6 ± 4.7%), P_{aCO_2} (group III = 46.6 ± 1.3 torr [6.2 ± 0.2 kPa]; group II = 54.4 ± 2.6 torr [7.25 ± 0.34 kPa]), and surface tension minimum (group III = 8.8 ± 1.8 dyne/cm; group II = 20.0 ± 2.0 dyne/cm), as compared with endotoxin without treatment (group II) 6 hours after endotoxin infusion. However, surfactant instillation did not significantly improve P_{aO_2} (group III = 62.8 ± 6.8 torr [8.4 ± 0.9 kPa]; group II = 50.3 ± 3.7 torr [6.7 ± 0.49 kPa]) or reduce the amount of pulmonary edema (group III = 7.1 ± 0.39 ratio; group II = 6.8 ± 0.24 ratio) seen 6 hours following endotoxin injection. Histologic analysis showed that endotoxin caused edema accumulation around airways and pulmonary vessels, and a large increase in the number of marginated leukocytes with or without surfactant treatment. Surfactant treatment significantly increased the total number of leukocytes in the pulmonary parenchyma. CONCLUSIONS: We conclude that endotoxin caused lung injury typical of ARDS as demonstrated by pulmonary edema, an increase in P_{aCO_2} and a decrease in P_{aO_2}, a decrease in static lung compliance, and inhibition of surfactant function. Exogenous surfactant treatment effected only moderate improvements in lung function (ie, reduced venous admixture and restored surfactant function) in this sepsis-induced ARDS model.

With the Reader Service Reply Card, You Can Stop Searching and Start Buying.

Get the facts on all the products and services advertised in this issue easily and quickly. The computerized Reader Service Reply Card does it all. Simply fill in your name and address, check the appropriate boxes, and mail or fax it.

Determinants of Aerosolized Albuterol Delivery to Mechanically Ventilated Infants—DM Coleman, HW Kelly, BC McWilliams. Chest 1996;109(6):1607-1613.

An in vitro lung model and a volume ventilator were used to evaluate the delivery of aerosolized albuterol through an infant ventilator circuit. We compared the following: continuous nebulization (CNA) and intermittent nebulization (INA); various nebulizer gas flows, 5.0, 6.5, and 8.0 L/min; and duty cycle of 33% and 50%. The efficiency and consistency of aerosol delivery by metered-dose inhaler (MDI) with 4 different spacer devices and by nebulizer positioned at the manifold and at the same position as the MDI were also evaluated. A volume ventilator (Servo 900B) was used with settings selected to reflect those of a moderately to severely ill 4-kg infant. A 3.5-mm endotracheal tube was used in all experiments. A specific type of nebulizer used (Airlife Misty Neb; Baxter; Valencia CA) and several spacers were studied (Aerochamber and Aerovent, Diemolding Healthcare Division, Canastota NY; ACE, Monaghan Medical Corp, Plattsburgh NY); and an incline MDI adapter (Instrumentation Industries Inc, Pittsburgh PA). CNA delivered significantly more aerosol to the lung model (4.8 ± 0.6% of the starting dose) than INA (3.8 ± 0.3%; $p < 0.01$). There was a significant stepwise decrease in aerosol delivery with increasing nebulizer flow (4.8 ± 1.3% at 5.0 L/min; 3.7 ± 1.1% at 6.5 L/min; and 2.7 ± 1.1% at 8.0 L/min). Increasing duty cycle did not significantly affect delivery. Overall the spacers with MDI were more efficient than the nebulizer in either position delivering about twice the percentage of the starting dose than the nebulizers. All modes of delivery, except the Aerochamber, demonstrated a marked degree of variability. Most of the starting dose of albuterol either remained in the nebulizer (30.4 ± 6.0% at 5.0 L/min and 25.3 ± 4.1% at 8.0 L/min) or was deposited in the inspiratory tubing (34.7 ± 0.7% at 5.0 L/min and 43.7 ± 4.9% at 8.0 L/min) in our system. In conclusion, we have confirmed that aerosol delivery depends on the mode of delivery and the operating conditions. Although delivery with an MDI and spacer is more efficient than a nebulizer, both methods may produce high variability depending on the method or spacer used.

Surfactant Content in Children with Inflammatory Lung Disease—AM LeVine, A Lotze, S Stanley, C Stroud, R O'Donnell, J Whitsett, MM Pollack. Crit Care Med 1996;24(6):1062-1067.

OBJECTIVE: To determine surfactant profiles of tracheal secretions in mechanically ventilated children with respiratory failure secondary to bacterial pneumonia, viral pneumonitis, adult respiratory distress syndrome (ARDS), and cardiopulmonary bypass. DESIGN: Prospective, cohort study. SETTING: Tertiary, multidisciplinary, pediatric intensive care unit. PATIENTS: One hundred twenty pediatric patients with respiratory failure requiring mechanical ventilation. INTERVENTIONS: Routine tracheal aspirates were collected from children with bacterial pneumonia, viral pneumonitis, ARDS, postcardiopulmonary bypass, and a postsurgical control group. Samples were obtained on days 1, 2, 3, after every week of intubation and on the day of extubation. MEASUREMENTS & MAIN RESULTS: The tracheal aspirates were analyzed by high-performance liquid chromatography for lecithin/sphingomyelin ratios and by enzyme-linked immunosorbent assay for surfactant proteins A and B. Lung compliance and the oxygenation index were measured on each day of sample collection. On day 1, patients with bacterial pneumonia, viral pneumonitis, and ARDS had decreased lecithin/sphingomyelin ratios ($p < 0.001$), and those patients with bacterial pneumonia and viral pneumonitis had decreased surfactant protein A/protein concentration ($p < 0.001$). The lecithin/sphingomyelin ratios and surfactant protein A/protein concentration were significantly different among the groups ($p < 0.001$), with the bacterial pneumonia and viral pneumonitis groups having higher lecithin/sphingomyelin ratios and increased surfactant protein concentrations before extubation. Pulmonary compliance was lower and the oxygenation index was higher than controls ($p < 0.001$) in patients with bacterial pneumonia, viral pneumonitis, and ARDS. Pulmonary compliance was correlated weakly with lecithin/sphingomyelin ratio ($r^2 = 0.11$, $p < 0.001$) and surfactant protein A/protein concentration ($r^2 = 0.03$, $p < 0.05$). Surfactant protein B was similar in the diagnostic groups. Surfactant content in tracheal secretions from cardiopulmonary bypass patients was equivalent to controls. CONCLUSION: Abnormal tracheal aspirate surfactant phospholipids and surfactant protein A were noted in children with bacterial pneumonia, viral pneumonitis, and ARDS, but not in children on cardiopulmonary bypass.

4th Annual Postgraduate Course

Respiratory Care and Medical Direction in a Changing World

Saturday, November 2

During the 42nd International Convention & Exhibition, the AARC will present this one-day post-graduate course for physicians only.

The program is approved for 6 hours in Category I of the Physician's Recognition Award of the American Medical Association. Topics include the future of respiratory care, a primer on concepts and terms in health care today, the role of the medical director in today's hospital, medical direction beyond the acute care hospital, an update on ARDS, patient protocols and clinical pathways in respiratory care, clinical practice guidelines, departmental restructuring, and how to select ventilators.

Encourage your medical director to attend this informative program.

Call the AARC today at 214-243-2272 (Fax 214-484-2720) and request that a complete description of the course and registration form be sent to your medical director or other interested physician.

Don't Miss the Research Symposium at the 42nd International Convention & Exhibition in San Diego

Presented by the Editorial Board of
RESPIRATORY CARE
Wednesday, November 6
9:00-10:55 am • Rooms 1A-B

9:00-9:15 am
Program Overview
Joseph L Rau Jr PhD RRT
Georgia State University, Atlanta GA */Chairing*
Introduces and reviews the 1993-1995 symposium topics and the key topics of knowledge in a research project.

9:20-10:05 am
Ethics of Human Research and Institutional Review Boards
Dean R Hess PhD RRT
Massachusetts General Hospital, Boston MA
Defines "ethics." Explains the rationale for board regulations, using examples. Outlines regulations: exempt, expedited, full review studies. Details the key elements in an Informed Consent Form.

10:10-10:55 am
Population and Samples: Concepts and Examples
Joseph L Rau Jr PhD RRT
Describes two examples of sample results. Defines terms: target population, accessible population, sample. Explains analysis of examples using these distinctions. Details example of population criteria used to select a nonrandom sample.

A Respiratory Care Assessment-Treatment Program: Results of a Retrospective Study

Kevin L Shrake MA RRT, John E Scaggs BS RRT, Kevin R England MBA, Joseph Q Henkle MD, and Lanie E Eagleton MD

BACKGROUND: Due to the success of a respiratory care assessment-treatment pilot study on the orthopedic floor of our hospital, the Executive Committee of the medical staff approved expansion hospitalwide. EXPANSION TECHNIQUE: Each nursing unit was included in the project in a systematic fashion after group and individual communication had occurred. Patient assessment training sessions were conducted for the respiratory staff to allow for 24-hour coverage of all nursing units. EVALUATION METHODS: The evaluation period extended from October 1993 through October 1995. Daily monitoring activities tracked general data elements on all patients. A series of retrospective audits were conducted on a subset of patients to track a more detailed set of data points. The utilization and costs of respiratory services provided to patients in 20 selected DRGs were compared between a preprotocol period (April, May, and June 1993) and the same 3-month period in 1995. EVALUATION RESULTS: During the 2-year evaluation, daily monitoring revealed that 4,420 patients were assessed and treated by respiratory care practitioners (RCPs), which included 11,050 initial and follow-up evaluations. Retrospective audits on 595 of those patients indicated that participation in the protocol process increased significantly from 66% to 78% ($p = 0.004$). Of the patients on protocols, 81-88% were being tapered, placed on treat-as-needed status (ie, prn), discontinued, or readjusted to their home regimen prior to discharge. Physicians accepted the RCPs' treatment plan 90-97% of the time without intervening. Treatment volume decreased, resulting in identified cost savings of $15,337 over a 3-month evaluation period (annualized savings, $61,348). CONCLUSIONS: The positive results of a respiratory patient assessment-treatment pilot project were successfully duplicated when the process was expanded hospitalwide. RCPs in our hospital were able to demonstrate value by implementing care plans that resulted in cost savings. [Respir Care 1996;41 (8):703-713]

Mr Shrake is Administrator and Mr Scaggs is Evening Shift Supervisor, Cardio-Pulmonary Services, and Mr England is Administrator, Clinical Resource Management—Memorial Medical Center; Dr Henkle is Associate Professor and Dr Eagleton is Associate Professor and Chief, Division of Pulmonary Medicine, Southern Illinois University School of Medicine—Springfield, Illinois.

Reprints: Kevin Shrake, Administrator, Cardio-Pulmonary Services, Memorial Medical Center, 800 North Rutledge Street Springfield IL 62781.

Background

Appropriate utilization of hospital resources is an essential part of controlling cost and is congruent with ongoing initiatives driving health-care reform. It has been shown that patient assessment-treatment programs can result in cost savings, either by eliminating unnecessary care or by decreasing length of stay through appropriate treatment,[1-6] and can be implemented without adverse changes in clinical outcome.[6-9]

During July, August, and September 1993, a pilot respiratory care assessment-treatment program was implemented on the orthopedic surgery floor (OSF) in our institution[8] using protocols developed from the American Association for Respiratory Care (AARC) Clinical Practice Guidelines.[10-40] During the pilot, no changes in patient outcomes were noted while treatment volumes decreased, resulting in identified cost savings for the 3-month period. Due to the positive results of the pilot, the Executive Committee of the medical staff granted approval to expand the process housewide.

The purpose of this study was to determine whether the success of the patient assessment-treatment program piloted on the OSF could be duplicated on a larger scale, with sustained positive results over a 2-year period. Success would be measured by evidence of increased use of the system with minimal physician intervention, while controlling utilization of services that would result in cost savings.

Expansion Technique

All the major components of the patient assessment-treatment program were in place to expand housewide. Therefore, the major aspects of the expansion technique centered around providing proper communication to the nursing staff and planning for increased numbers of trained patient-care evaluators.

Communications

An implementation plan was established to bring each nursing unit 'on line' in a systematic fashion. This allowed for proper communication with the nurses involved. Experience during the pilot project had clearly indicated that if members of the nursing staff viewed the process in a positive way, they became key advocates to solicit physician participation, thus making it easier to achieve the ultimate goals of the program. The communication process was first initiated with the Nurse Managers in a group meeting during which the order of unit implementation was determined. A 6-month implementation schedule was established for transition to the use of protocols on all nursing units. The Nurse Managers requested that presentations be made to the Unit-Based Nursing Councils, which are the self-governing bodies of each nursing unit. Each member of a Council was responsible for communicating the purpose of the respiratory assessment-treatment program to a specific number of peers via one-on-one communications. This was followed with direct communication by the respiratory care practitioners (RCPs) to the nursing staff, prior to implementation on each unit, to answer questions and alleviate concerns.

Patient-Care Evaluators

The pilot project had been completed with only 10 patient-care evaluators, (rather than utilizing all staff as evaluators) to allow closer quality control. These individuals were selected based on their prior demonstration of good assessment and communication skills. To further improve their knowledge base, the 10 original evaluators completed a 2-day certificate course in patient assessment offered by a local community college. This course provided a consistent approach to patient assessment and included 'hands on' practice using patient case studies. To expand the process hospitalwide, it was necessary to train additional staff. This involved one-on-one training by the original core group of patient-care evaluators for all staff members. Group meetings with the Pulmonary Administrator to provide direction regarding such issues as physician notifications, charting formats, and quality review techniques were also conducted. Performance and completion of appropriate training was documented.

Evaluation Methods

Evaluation Period

The evaluation began, after Executive Committee approval for our patient assessment-treatment program, in October 1993 and concluded for the purposes of this study in October 1995.

Daily Monitoring

The Cardio-Pulmonary Department tracked, on a daily basis, the percentage of our total patients who were on respiratory protocols. The RCPs were trained to report "red flag events" to their supervisor. Such events included orders from physicians to discontinue respiratory protocols or to intervene and change a treatment plan that was being carried out by the RCP. Such examples were automatic cues to make a follow-up contact with those physicians to discuss how we could have better assisted them. The RCPs also identified patients who were not on protocols and contacted the ordering physician in an attempt to convert from the conventional-orders process to our assess-and-treat program. The daily monitoring allowed us to track the total number of patients on our program as well as the total number of patient evaluations conducted.

Retrospective Audits

A series of 3 retrospective audits were conducted, approximately 3 months apart, during the last 9 months of the evaluation period. These audits were completed by patient evaluators and monitored a more specific series of data elements on a smaller sample than what was being tracked for the entire patient population. These data were extracted from the departmental protocol records (Fig. 1). During each audit, the records of all patients managed by protocol during the most recent 30-day period were reviewed. By periodically sampling all records for a designated time period, we attempted to remove any biases that might result from a more selective audit pro-

cess. Patient evaluators were used as auditors because they had the best understanding of how to record the data and could provide immediate feedback to their colleagues on the success of the program and on aspects requiring improvement. A number of data points could be chosen for audit to evaluate the protocol process. Some of the elements that we consistently tracked were:

- Number of patients on protocols
- Percent of protocol patients compared to the total patients receiving respiratory care
- Number of physicians ordering protocols
- Type of protocol ordered
- Number and percent of time physicians accepted the care plan without intervening
- Number and percent of patients whose treatment frequency was tapered prior to discharge
- Number and percent of patients who were discontinued or placed on treat-as-needed, or prn, status prior to discharge
- Number and percent of patients tapered to their home regimen prior to discharge if on home therapy
- Number and percent of patients reassessed within 48-72 hours of their last assessment

The percentages of patients on protocol and the percentages of time the physician agreed with the care plan during the 3 audit periods were compared using the χ^2 test.[41]

Clinical Resource Management

A focused evaluation of data provided by the Clinical Resource Management Department allowed us to compare cost information for the 20 Diagnosis Related Groups (DRGs) that utilized respiratory care and had the highest patient volume during specific periods before and after initiation of the protocol process. The preprotocol period was April, May, and June 1993 (pilot project July-September 1993). The postprotocol comparison period was April, May, and June 1995.

MEMORIAL MEDICAL CENTER
PULMONARY MEDICINE
PROTOCOL RECORD

Original Order Date
Ordering Physician
Type of Protocol

ADDRESSOGRAPH

History
Diagnosis

INITIAL ASSESSMENT

HR	F_{IO_2}/OX	Breath Sounds	X-Ray	Additional Information	Signature
RR	B/P				Date Time
H&H	Temp	Sputum			Therapy Needed
HT/WT	Albumin				

REASSESSMENT

Date	Time/ Signature	RR	HR	T	F_{IO_2}/OX	Cough/ Sputum	Breath Sounds	Next Evaluation	Progress Notes	Current Therapy/ Frequency	Additional Comments

Fig. 1. Departmental record used by RCPs when administering respiratory care via the assessment-treatment process. This document is not part of the medical record but is used as a data sheet for the RCP and a source of information for retrospective audits.

By comparing the same 3-month period in different years, we attempted to minimize differences in length of stay and resource utilization that could be attributed to seasonal variations. The data were also inflation and case-mix adjusted in an attempt to control other variables that could affect the validity of the comparisons. The effect of inflation was adjusted by using 1995 dollars for the unit variable costs when calculating the average variable costs in both the 1993 and 1995 evaluation periods. Case mix was adjusted by comparing the actual respiratory care costs incurred by patients during 1995 with costs that were incurred with a patient population using the same DRG case weight in 1993. The significance of the respiratory care variable cost differences were evaluated using a 2-tailed paired *t* test.[41]

Evaluation Results

Daily Monitoring

During the 2 years of study, 4,420 patients were assessed and treated by RCPs via the protocol process. A combination of 11,050 initial and follow-up evaluations were performed on these patients. In addition to managing the routine orders received for protocols, the RCPs made, on the average, 10 physician contacts/day to solicit the use of the protocol process for patients ordered on specific respiratory care. An average of 5 physician contacts/month were made to address red flag events when physicians intervened with the care plan being carried out by the RCP.

Retrospective Audits

In addition to the daily monitoring of the assessment-treatment program, periodic audits were completed to provide more specific data to the RCPs. These data were used to assess effects of the process and to identify opportunities for quality improvement. The results of the 3 audits conducted during 1995 are shown in Table 1. The total sample was 595 patients, which represented 13% of the total population of protocol patients during the previous 2 years (4,420 patients total). Trends suggest that the respiratory care assessment-treatment program is being accessed by a large number of physicians who are ordering protocols primarily in the generic form rather than directing the RCP to administer a specific protocol such as "bronchodilator protocol." This allows the RCP the maximum freedom to select the appropriate treatment for the patient. The percentage of patients on protocols as compared to the total patients receiving respiratory care increased significantly from 66% to 78% from March 1995 to October 1995 ($p = 0.004$). The physicians are accepting the treatment protocols suggested by the RCPs a large part of the time without intervening with alternate orders. The percentage increased significantly from 90% in March 1995 to 97% in October 1995 ($p = 0.019$). Most patients are being tapered, placed on prn-only status, discontinued, or readjusted to their home regimen prior to discharge. Percentages fluctuated between 81-88% during the 3 audit periods. Almost all patients (95-99%) are being re-evaluated within a 48-72 hour period for potential changes in their care plan.

Table 1. Results of Audit of 595 Charts of Patients Assessed and Treated via the Protocol during 1995.

Data Element Evaluated	March 1995	June 1995	October 1995
Number of protocol patients/total number of patients receiving respiratory care (%)	228/345 (66)	190/252 (75)	177/227 (78)
Number of physicians ordering protocols	109	95	105
Number (%) ordering generic protocol rather than specific protocol	171 (75)	161 (85)	152 (86)
Number (%) of times physician agreed with care plan	206 (90)	179 (94)	172 (97)
Number (%) of patients whose treatment frequency was tapered prior to discharge	88 (39)	61 (32)	67 (38)
Number (%) of patients who were discontinued or placed on prn status prior to discharge	55 (24)	55 (29)	23 (13)
Number (%) of patients who were tapered to their home regimen prior to discharge	52 (23)	51 (27)	53 (30)
Number (%) of patients who were re-assessed within 48-72 hours of last assessment	217 (95)	180 (95)	175 (99)

Cost Savings

The cost savings identified during 3-month pre- and post-program evaluations are summarized in Table 2. The utilization and cost savings were extracted from our institution's internal cost accounting, case-mix, and patient-billing systems, and were not derived from cost-charge ratios. The cost savings identified include only the variable costs associated with providing those particular services. Included in our institution's variable costs are direct labor, materials, and fringe benefits. Allocated fixed costs have been excluded from this analysis because those amounts tend not to fluctuate with changes in utilization. As a result, the variable amount measures the actual reduction in operating expenses resulting from the RCPs' use of the patient assessment-treatment system. The average cost and utilization figures reflected in Table 2 are based on total hospital discharges of patients in the 20 highest volume

Table 2. Financial Impact of Respiratory Care Assessment-Treatment Program Comparing a 3-Month Evaluation Period to a Preprogram Period*

Service Description	Unit Var Cost($)	Base Period April 93-June 93 Avg Var Cost($)	Base Period April 93-June 93 Avg Units	RT Protocol Period April 95-June 95 Avg Var Cost($)	RT Protocol Period April 95-June 95 Avg Units	Variance from Base Avg Var Cost($)	Variance from Base Avg Units	Savings Cost($)	Savings Units
Aerosol Oxygen	0.09	0.63	7.0	0.21	2.3	0.42	4.7	376.32	4,181.4
Incentive Setup	14.63	6.51	0.4	4.33	0.3	2.19	0.1	1,956.18	133.7
Incentive Daily	7.86	5.66	0.7	0.00	0.0	5.66	0.7	5,065.77	644.5
IPPB	7.79	6.33	0.8	2.70	0.3	3.63	0.5	3,250.92	417.3
Nebulizer Rx	6.82	91.94	13.5	97.73	14.3	(5.80)	(0.9)	(5,189.07)	(760.9)
Pulse Oximetry	6.22	5.98	1.0	4.51	0.7	1.47	0.2	1,311.92	210.9
Oxygen	0.09	7.15	79.4	3.92	43.6	3.23	35.9	2,890.46	32,116.2
CPT	7.61	12.93	1.7	7.48	1.0	5.45	0.7	4,875.35	640.7
Oxygen Supplies								799.56	
Totals		137.13	104.5	120.88	62.5	16.25	41.9	15,337.41	37,583.8

*Numbers have been rounded. Variable unit costs were used to calculate average variable costs of 798 patients during the 3-month base period and for 895 patients during the 3-month respiratory care protocol period. Average cost savings variance from the base period was calculated and used to document total cost savings. IPPB = intermittent positive pressure breathing; CPT = chest physiotherapy.

DRGs that incorporate respiratory care in our facility, during the 3-month comparative time periods (April-June 1993 and April-June 1995). Outlier cases as defined by the Health Care Financing Administration[42] have been excluded from the analysis. When the 3-month periods were compared, a significant reduction was seen in operating expenses of $16.25/patient, ($p = 0.007$), resulting in a total savings of $15,337 including oxygen supply savings). If utilization and patient referrals remain constant, this extrapolates to an annual cost savings of $61,348. These cost savings correlate with the utilization control trends demonstrated in Table 1 and not to savings associated with the overall decline in patient stay during that period. This is supported by clinical resource utilization trends for ancillary services that indicate that the highest intensity of services occurs during the first few days of a patient's stay. Because these data were also case-mix and inflation adjusted, the costs savings can be attributed neither to differences in severity of illness between the two populations nor simply to inflationary cost increases.

Discussion

Building on Success

A key to gaining approval to implement protocols on a hospitalwide scale was our ability to build on the success demonstrated during the pilot program. Many of the initial fears brought forth by nurses and physicians during the pilot program either did not materialize or were successfully addressed. This made the 'sales job' to other physicians easier as the scope of the project grew. Despite this luxury, we invested a great deal of time in attending physician department meetings to 'sell' the merits of the program. We also focused on meeting with resident staff because they were providing coverage on 55% of the patients admitted to our 535-bed, university-affiliated teaching hospital. The participation of the Pulmonary Medical Director or his Associate in the group meetings with the Pulmonary Administrator to outline the protocol process to their physician colleagues proved to be an effective technique. However, we attribute the program's growth to effectively selling the process on a daily basis to our physician users. It is one thing to stimulate interest in a program during a group meeting but quite another to produce a product that the group finds advantageous and chooses to use again. Each patient care evaluator was challenged to develop a personal 30-second 'infomercial' and present the physicians with protocols (Memorial Medical Center Respiratory Protocols). A typical encounter is:

> Dr Jones, we received an order for Mr Thompson in B618 for a small volume nebulizer with albuterol sulfate. As you may or may not be aware, we have a respiratory care assessment-treatment program. By ordering "Respiratory Care Protocol," your patient will be evaluated by an RCP, and if it is indicated, appropriate respiratory care will be initiated utilizing physician-approved protocols. A care plan will be established and summarized for you in the patient progress notes. Therapy will be tapered, changed, discontinued, or adjusted to match home therapy regimens with important events recorded in the progress notes. If, at any time, you feel that the care plan is not appropriate, you, of course, always have the ultimate decision-making authority and may intervene with specific orders. There are safeguards

> built into the process that require the RCP to make a physician contact for such things as adverse reactions to drugs or therapy frequencies greater than every 4 hours. Here is a copy of our pocket guide to respiratory protocols. Would you be willing to give me an order for "Respiratory Care Protocol" for Mr Thompson?

This one-on-one technique has proven to be effective, but as with all successful sales experiences, one ultimately must have a good product to offer. We believe that a persuasive RCP with good oral communication skills may account for the first order for protocols from a particular physician, but subsequent orders are acquired due to the merits of the process. We are pleased with our current 78% participation rate for what has been designed as a strictly voluntary program.

Anecdotal Observations

Over the past 2 years, the protocol system has had a positive impact on the nursing units as it has evolved in both scope and direction. We believe that respiratory care protocols succeeded with the nursing staff because the process assists them in providing better care to their patients. In fact, at the beginning the nursing staff was in some respects more accepting of the respiratory protocols than were some RCPs. Our nursing staff has taken full advantage of respiratory protocols. Respiratory concerns are still directed to the attending physicians, but increasingly the contacts are made to obtain respiratory protocol orders for their patients. Nurses have come to rely on the knowledge and judgment of the RCPs. They trust that their patient's respiratory needs will be correctly and personally assessed at the bedside. If a pulmonary complication requires further physician involvement, the RCPs make a call after consulting with the nurse. The nursing staff has appreciated this support and has shown confidence that the RCPs will actively communicate assessments and care plans, not only on the patient's chart but also with them personally.

Before the use of protocols, RCPs outside of the Intensive Care Units worked almost completely independent of nursing. Respiratory protocols helped change the entire relationship between the RCPs and the nursing staff. Bonds have been developed due to the way that the process encourages communication and teamwork. This has been a refreshing environment to experience given the chaos that is present in the changing world of health care.

The team approach that we have developed with nursing has provided other opportunities to work together. In the past year, the nursing staff has invited RCPs to participate in their hospitalwide nursing skills days. The event had been designed as a continuing education program strictly for nurses, but RCPs are now key participants and instructors.

Our Cardio-Pulmonary Services Department has been able to reap other direct rewards from the protocol process. Most importantly, they have demonstrated value to our organization. Some hospitals have sought to save money by decentralizing or eliminating respiratory care departments. Our facility has chosen to maintain all the advantages of a multiskilled, central department that deploys personnel wherever and whenever they are needed. At the same time, we have looked to implement programs such as respiratory protocols in an attempt to enhance teamwork, improve patient care, and lower costs through utilization control.

We believe that RCPs have had a positive impact on patient care. An anecdotal account of a patient situation that occurred in the early stages of our program involved only a few RCPs but enhanced the morale of the entire department. The patient in question was a 34-year-old, black man who presented with ligament damage to the right knee. A man of superb physical condition, he was a karate instructor whose injury occurred during routine sparring. Although respiratory care protocols were ordered, our staff did not expect a respiratory challenge during the course of the planned 2-day admission. Everything initially went well. The arthroscopic surgery on the damaged knee was a complete success. The patient was returned to his room following surgery and the remainder of the day passed without incident. According to procedure, an RCP fully assessed the patient following surgery. The initial workup revealed the obvious—a young man of enviable physical health and physique. However, the assessment on the morning after surgery revealed a single disturbing fact. The patient's oxygen saturation as measured by pulse oximetry had dropped to 82%. This was noted in the chart and, as provided by protocol, supplemental oxygen via nasal cannula was initiated. The patient was assessed twice more that day, and each time a low oxygen saturation was noted even with the patient on supplemental oxygen. The attending physicians were paged upon each assessment but believed the readings to be erroneous because they did not match the clinical picture. The patient showed no other signs or symptoms and when questioned stated that he was not short of breath. An initial request by the RCP for arterial blood gas analysis was denied. At the end of the first postoperative day, discharge on schedule was still planned. Due to the mounting documentation of concerns expressed by the RCPs, a pulmonologist was called to consult on the second postoperative day. An arterial blood sample was drawn and analysis revealed a P_{aO_2} of 53 torr and oxygen saturation of 83%. Further testing revealed that the patient had suffered a pulmonary embolism. It was believed that his unique physical conditioning had masked the usual signs and symptoms of the condition. The patient's discharge was postponed. During the several days of heparin therapy that ensued, the RCPs followed him closely. His oxygenation status gradually improved, and he was discharged without incident on postoperative Day 6. Did the RCPs save a life through the use of protocols? We will never know, but the respiratory care staff was understandably proud of their contribution to this patient's care.

Undertreatment vs Overtreatment

Although the emphasis of respiratory care assessment-treatment programs is often on reduction of therapy, some studies have suggested that patients may also be undertreated.[4,8] Our own data, as shown in Table 2, confirm that utilization of some treatment modalities actually increased with the use of protocols as compared to the base period. Accurate patient assessments identify the need to treat as well as not to treat. These utilization trends tend to vary with case-mix severity.

Financial Success Demonstrated

The financial success of the program has resulted from a reduction in utilization of respiratory services via more aggressive tapering and discontinuing of therapy. All of our quantification of savings has been in terms of true hospital costs rather than charges. Because most patients who receive respiratory care in our facility are on some form of fixed payment, hospital charges are economically less important than consumption of respiratory services. The demonstrated cost savings identified in Table 2 is three times that documented in our original pilot study,[8] which encompassed only one nursing unit as opposed to a hospitalwide initiative. This suggests that we were successful in expanding the financial benefits of the program. Although the results are important, they do not represent all the cost savings associated with the process. The protocol participation rate during the months of April through June 1995 gradually increased to 75%. As higher participation rates are sustained, costs savings should increase. Reported cost savings are also understated because it is likely that there were additional savings associated with other DRGs that did not make our 'top 20' utilization list. In addition, our results did not include costs savings that occurred from performing a patient evaluation and choosing to provide no treatment to patients who might otherwise have been ordered on therapy. Costs have also been reduced by placing patients on self-administered care once they have been tapered to their home regimen. The entire process has provided an effective tool for the physicians who solicit the assistance of RCPs in an attempt to lower their hospital cost/case profile. We believe that hospitals choosing to use RCPs in this fashion will reap the financial benefits and also improve employee satisfaction through enhanced professional standing.

Staff Satisfaction

The process of implementing a patient assessment-treatment program involved important changes on the part of the staff. During the change process, even though most staff members agreed in concept with the benefits of protocol use, there were 'growing pains' associated with the work created by the increased time spent evaluating patients, documenting care plans, and communicating with physicians and nurses. Now that we are 2 years into the process, there is a growing sense of pride among our staff in regards to what has been accomplished. As our health-care system continues to experience massive change driven by the desire to contain costs, it has become increasingly clear to our staff that RCPs must demonstrate value to their organizations. The protocol process has provided a vehicle to demonstrate value and has thus enhanced the RCPs' overall image in our institution. This has resulted in a perceived improvement in staff morale in relationship to satisfaction with the patient care role they are providing and the interactions they are experiencing with their professional colleagues. We will attempt to measure this perceived improvement in morale via an employee-satisfaction survey scheduled for completion during 1996.

Quality Monitoring Goals

Establishing a statistically valid improvement in quality of care as a result of our patient assessment-treatment program was beyond the scope of this study. However, the fact that the physicians intervened so infrequently with the RCP's care plan is a positive indicator of quality. Several other general quality monitoring tools were used during the 2-year evaluation period. Although they do not specifically validate the quality of the protocol process, the results are encouraging. Hospital mortality compared favorably with the benchmark of the Maryland Quality Indicator Project.[43] This project initiated in 1988 as part of a research grant originally managed by the Maryland Hospital Association is now self-sustaining and is recognized as a premier benchmarking tool. Comparative data are provided from 50 multihospital systems and allied hospital associations representing 900 acute care hospitals. In addition to the Maryland Project data, there were no unexpected deaths attributed to the use of the respiratory assessment-treatment program as reported by the Quality Monitoring Department. The Risk Management Department reported 120 respiratory-related incidents during the evaluation period. These incident reports related to order errors on nonprotocol patients, medication errors, loss of airway, and equipment failures. None of these reports was related to problems or complications associated with the use of protocols. These data suggest that the patient-incident system is being utilized. Therefore, the fact that no protocol-related incidents were identified is encouraging. Overall hospital average length of stay (ALOS) declined from 7.3 days in October 1993 to 6.2 days in October 1995. This is a national trend that is influenced by a variety of factors including increased pressures from insurance companies to discharge patients sooner. The use of protocols cannot be credited for this decline. However, we are pleased that the ALOS has declined during this period of protocol use. We have observed that RCPs still have a tendency to err on the side of treating rather than not treating patients whose indications for therapy are questionable. This tends to minimize disagreements with physicians but suggests that there may

be further opportunities to decrease costs without impacting quality of care as the use of the protocol process matures. This will likely occur as increasing financial pressures provide greater incentives to work in a collaborative fashion to develop the most cost-effective and efficacious care plan.

Improved Communication

Improved communication is difficult to measure, but our patient assessment-treatment program has clearly increased the frequency of communications of RCPs with physicians and nurses. According to the opinions of the RCPs, relationships have improved. This is evidenced by the increasing number of hospital initiatives that RCPs have been asked to participate in that were not afforded to them prior to the implementation of the protocol process. By establishing collaborative relationships through the use of protocols, it has become natural for RCPs to be included as part of the team in important issues such as restructuring work projects, multidisciplinary charting documents, and information systems networking.

Advice to Would-Be Implementors

Clinical resource management efforts continue to be one of the most important initiatives that acute care hospitals can undertake in the competitive, cost-conscious, rapidly changing world of health care. Every institution has its own political culture that influences the ease (or difficulty) associated with establishing an assessment-treatment program. Developing systems that can reduce cost while maintaining high quality care fits the strategic direction of most health-care organizations today. Even if an assessment-treatment program cannot be developed on a full-scale basis, a department can begin with the preparatory work of involving the medical director, developing protocols, educating staff, and looking for opportunities to conduct pilot studies. Eventually, what may seem impossible now may turn out to be desirable when new incentives (financial or otherwise) develop. It is not necessary to 'reinvent the wheel.' Numerous examples of protocols[44] and their current uses[45] are available in the literature.

Our experience[8] suggests that a pilot program is a good way to gain experience and work through problems of a new system on a small scale. A pilot program also allows for the collection of data to support the use of protocols on a larger scale. It is advisable to expand systematically to develop confidence and establish success stories. Poor performance with a few patients can destroy a program, even if the majority of patients are cared for appropriately. Placing emphasis on the training of staff in patient-assessment skills lends credibility to the program and increases the chances of success.

A major point to emphasize when selling the potential merits of such a protocol system is that the practice of having 100% of the respiratory care currently ordered administered by caregivers with lesser skills (and, therefore, cheaper) is not cost effective. Studies have suggested[4] and our own experience supports that much of the ordered respiratory care in hospitals today is inappropriate. We believe that using the more sophisticated patient-assessment skills of RCPs to assist physicians in monitoring appropriate use of clinical resources and then allowing them to also deliver that care is a cost-effective system.

Conclusions

We successfully expanded a patient assessment-treatment program from a pilot study on a single nursing unit to a hospitalwide initiative in a 535-bed university-affiliated teaching facility. The criteria established to measure our success indicated that our goals were achieved. Participation in the program was high with an excellent percentage of the RCPs' care plans accepted by the physicians without intervention. Overall utilization of respiratory therapy declined, resulting in a 3-month cost savings of $15,337 (annualized savings rate of $61,348). Positive results of a successful patient assessment-treatment program can be used as a mechanism for RCPs to demonstrate value to their organizations.

REFERENCES

1. Hart SK, Dubbs W, Gil A, Myers-Judy M. The effects of therapist-evaluation of orders and interaction with physicians on the appropriateness of respiratory care. Respir Care 1989;34(3):185-190.
2. Nielsen-Tietsort J, Poole B, Creagh CE, Repsher LE. Respiratory care protocol: an approach to in-hospital respiratory therapy. Respir Care 1981;26(5):430-436.
3. Tietsort J. The respiratory care protocol: a management tool for the '90s. AARC Times 1991;15(5):55-62.
4. Kester L, Stoller JK. Ordering respiratory care services for hospitalized patients: practices of overuse and underuse. Cleve Clin J Med 1992;59(6):581-585.
5. Mahlmeister MJ, Fink JB, Cohen NH. A strategy for reducing costs associated with pulse oximetry in noncritical care areas. Respir Care 1993;38(9):1005-1013.
6. Torrington KG, Henderson CJ. Perioperative respiratory therapy (PORT). A program of preoperative risk assessment and individualized postoperative care. Chest 1988;93(5):946-951.
7. Zibrak JD, Rossetti P, Wood E. Effect of reductions in respiratory therapy on patient outcome. N Engl J Med 1986;315(5):292-295.
8. Shrake KL, Scaggs JE, England KR, Henkle JQ, Eagleton LE. Benefits associated with an assessment-treatment program. Respir Care 1994;39(7):715-724.
9. Komara JJ, Stoller JK. The impact of a postoperative oxygen therapy protocol on use of pulse oximetry and oxygen therapy. Respir Care 1995;40(11):1125-1129.
10. American Association for Respiratory Care. Clinical practice guideline: incentive spirometry. Respir Care 1991;36(12):1402-1405.
11. American Association for Respiratory Care. Clinical practice guideline: pulse oximetry. Respir Care 1991;36(12):1406-1409.
12. American Association for Respiratory Care. Clinical practice guideline: oxygen therapy in the acute care hospital. Respir Care 1991;36(12):1410-1413.
13. American Association for Respiratory Care. Clinical practice guideline: spirometry. Respir Care 1991;36(12):1414-1417.

14. American Association for Respiratory Care. Clinical practice guideline: postural drainage therapy. Respir Care 1991;36(12):1418-1426.
15. American Association for Respiratory Care. Clinical practice guideline: patient-ventilator system checks. Respir Care 1992;37(8):882-886.
16. American Association for Respiratory Care. Clinical practice guideline: humidification during mechanical ventilation. Respir Care 1992; 37(8): 887-890.
17. American Association for Respiratory Care. Clinical practice guideline: selection of aerosol delivery device. Respir Care 1992;37(8): 891-897.
18. American Association for Respiratory Care. Clinical practice guideline: nasotracheal suctioning. Respir Care 1992;37(8):898-901.
19. American Association for Respiratory Care. Clinical practice guideline: bronchial provocation. Respir Care 1992;37(8):902-906.
20. American Association for Respiratory Care. Clinical practice guideline: exercise testing for evaluation of hypoxemia and/or desaturation. Respir Care 1992;37(8):907-912.
21. American Association for Respiratory Care. Clinical practice guideline: sampling for arterial blood gas analysis. Respir Care 1992;37 (8):913-917.
22. American Association for Respiratory Care. Clinical practice guideline: oxygen therapy in the home or extended care facility. Respir Care 1992;37(8):918-922.
23. American Association for Respiratory Care. Clinical practice guideline: directed cough. Respir Care 1993;38(5):495-499.
24. American Association for Respiratory Care. Clinical practice guideline: in-vitro pH and blood gas analysis and hemoximetry. Respir Care 1993;38(5):505-510.
25. American Association for Respiratory Care. Clinical practice guideline: single-breath carbon monoxide diffusing capacity. Respir Care 1993;38(5):511-515.
26. American Association for Respiratory Care. Clinical practice guideline: use of positive airway pressure adjuncts to bronchial hygiene therapy. Respir Care 1993;38(5):516-521.
27. American Association for Respiratory Care. Clinical practice guideline: fiberoptic bronchoscopy assisting. Respir Care 1993;38(11): 1173-1178.
28. American Association for Respiratory Care. Clinical practice guideline: resuscitation in acute care hospitals. Respir Care 1993;38(11): 1179-1188.
29. American Association for Respiratory Care. Clinical practice guideline: intermittent positive pressure breathing. Respir Care 1993;38(11): 1189-1195.
30. American Association for Respiratory Care. Clinical practice guideline: bland aerosol administration. Respir Care 1993;38(11): 1196-1200.
31. American Association for Respiratory Care. Clinical practice guideline: ventilator circuit changes. Respir Care 1994;39(8):797-802.
32. American Association for Respiratory Care. Clinical practice guideline: delivery of aerosols to the upper airway. Respir Care 1994;39 (8):803-807.
33. American Association for Respiratory Care. Clinical practice guideline: neonatal time-triggered, pressure-limited, timed-cycled, mechanical ventilation. Respir Care 1994;39(8):808-816.
34. American Association for Respiratory Care. Clinical practice guideline: application of continuous positive airway pressure to neonates via nasal prongs or nasopharyngeal tube. Respir Care 1994;39(8): 817-823.
35. American Association for Respiratory Care. Clinical practice guideline: surfactant replacement therapy. Respir Care 1994;39(8):824-829.
36. American Association for Respiratory Care. Clinical practice guideline: static lung volumes. Respir Care 1994;39(8):830-836.
37. American Association for Respiratory Care. Clinical practice guideline: metabolic measurement using indirect calorimetry during mechanical ventilation. Respir Care 1994;39(12):1170-1175.
38. American Association for Respiratory Care. Clinical practice guideline: transcutaneous blood gas monitoring for neonatal and pediatric patients. Respir Care 1994;39(12):1176-1179.
39. American Association for Respiratory Care. Clinical practice guideline: capillary blood gas sampling for neonatal and pediatric patients. Respir Care 1994;39(12):1180-1183.
40. American Association for Respiratory Care. Clinical practice guideline: body plethysmography. Respir Care 1994;39(12):1184-1190.
41. Dawson-Saunders B, Trapp RG. Basic and clinical biostatistics. Norwalk CT: Appleton and Lang, 1994.
42. Health Care Financing Administration. Medicare program: changes to the inpatient hospital prospective payment system and fiscal year 1995 rates, final rule. Federal Register, vol 59, no. 169 (Sept 1, 1994), table 5, p 45447-45457.
43. Maryland Hospital Association. MHA Quality indicator project. project manual 1995: copies available: 1301 York Road, Suite 800, Lutherville MD 21093-6087.
44. Burton GG, Tietsort JA. Therapist driven protocols (TDPs)–a practitioner's guide. Torrance CA: Academy Medical Systems, 1993.
45. Weber K, Milligan S. Therapist-driven protocols: the state of the art (conference summary). Respir Care 1994;39(7):746-756.

MEMORIAL MEDICAL CENTER RESPIRATORY CARE PROTOCOLS

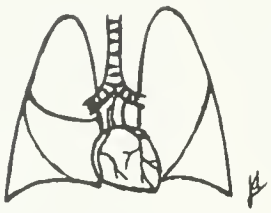
How to order:

Generic order: "Respiratory Protocol"

or

Specific order:

"Oxygen Protocol"
"Bronchodilator Protocol"
"Bronchial Hygiene Protocol"
"Volume Expansion Protocol"



What you receive:

- Patient evaluation by a Respiratory Care Practitioner
- Therapy initiated if appropriate, using physician approved guidelines
- Progress note reports with direct physician contacts when required
- Tapering and discontinuance of therapy
- Suggestions for use of pertinent services; Pulmonary Rehab, Home Care, sleep studies, etc.

Call for answers to questions: Respiratory Care Supervisor, Pager 1-234

OXYGEN THERAPY

PURPOSE:

To maintain oxygen saturation ≥ 90% or to prevent or avoid tissue hypoxia on patients ordered to receive oxygen.

THERAPEUTIC OBJECTIVES:

A. Treatment of hypoxemia.
B. Decrease work of breathing.
C. Decrease myocardial work.

INDICATIONS:

A. Documented hypoxemia—P_{aO_2} of < 60 mm Hg or S_{pO_2} < 90% in adults.
B. An acute care situation associated with suspected tissue hypoxia (e.g. pulmonary edema, drug overdose, carbon monoxide poisoning, anemia).
C. Clinical signs or symptoms of tissue hypoxia (e.g. tachycardia, tachypnea, dyspnea, cyanosis, diaphoresis, confusion, or chest pain).
D. Acute myocardial infarction with continuing pain, arrhythmias, or congestive heart failure.
E. Immediate postoperative period (post anesthesia room) until the patient is awake and vital signs are stable.

CRITERIA FOR USE OF A LOW-FLOW SYSTEM:

A. Adequate lung expansion
B. Respiratory rate: < 25 breaths/min
C. Ventilatory pattern: regular
D. Required liter flow < 6 L/min

CRITERIA FOR USE OF A HIGH-FLOW SYSTEM:

A. Required > 6 L/min or 0.45 F_{IO_2}
B. Rapid, shallow breathing pattern
C. Evidence of alveolar hypoventilation with CO_2 retention
D. Respiratory rate > 25 breaths/min

OUTCOME CRITERIA:

A. Titration of oxygen—Titrate O_2 to maintain S_{pO_2} ≥ 90% (≥ 92% for cardiac patients) allowing 15-30 minutes for stabilization. Re-evaluate based on patient clinical condition (minimum of every 24 hours). Oxygen may be discontinued when patient is able to maintain S_{pO_2} ≥ 90% on room air for 24 hours with stable vital signs (O_2 for post-op patients may be discontinued sooner if S_{pO_2} ≥ 92%).
B. Guidelines/Warnings: If patient is not tolerating titration process, return to previous settings, reassess patient and continue process as tolerated. If greater than 2 L/min or 30% oxygen is required to maintain S_{pO_2} ≥ 90%, the physician will be contacted for first setting and modality.

AEROSOLIZED MEDICAL THERAPY PROTOCOL

PURPOSE:

To administer aerosolized medication by the appropriate delivery system.

THERAPEUTIC OBJECTIVES:

A. Improve pulmonary airflow.
B. Improve sputum clearance.
C. Relieve or prevent dyspnea.
D. Improve oxygenation and/or carbon dioxide elimination.
E. To relieve airway edema.

INDICATIONS:

A. Wheezing.
B. Impaired clearance of secretions from the lungs.
C. Tracheobronchial mucosal congestion and laryngeal stridor.

CRITERIA FOR METHOD OF DELIVERY:

A. IPPB is indicated if:
   1. Ventilation is inadequate as in neuromuscular disease, kyphoscoliosis or when vital capacity is < 30% of predicted.
   2. Refractory atelectasis has developed.
B. Metered Dose Inhaler (MDI) with spacer (e.g. Aerochamber) is indicated if:
   1. Medication(s) available in this delivery method.
   2. Patient is alert/cooperative.
   3. Able to perform 3-second breath hold.
   4. Patient has demonstrated ability to use MDI effectively.
C. Small volume, hand-held nebulizer (HHN) is indicated if:
   1. Medication is not available in MDI form.
   2. Ventilation is not adequate.
   3. Patient demonstrates inability to use MDI effectively.

STANDARD PROTOCOL:

A beta agonist will be used QID & PRN as the standard for bronchodilator therapy. The current drug utilized is Albuterol Sulfate, 1/2 cc diluted with normal saline for IPPB and HHN or 3-4 puffs by MDI. Atrovent Solution 1/2 cc may be added in COPD patients for maximum bronchodilator effect.

NOTE:

If the Respiratory Care Practitioner believes

that the patient may benefit from vasoconstrictors such as Vaponephrine, an anti-inflammatory agent such as Intal, or a mucolytic agent such as Mucomyst, a physician contact will be made.

OUTCOME CRITERIA:

A. Guidelines/Warnings:
   Evaluate patient's clinical status for changes that indicate a need for change in the treatment plan such as:
   1. A pulse greater than 120 bpm, or if a pulse increase of 20 bpm occurs within 30 minutes of discontinuing therapy.
   2. Significant worsening of dyspnea or wheezing occurring during or within 30 minutes of discontinuing therapy.
   3. Worsening of patient's sensorium (e.g. patient becomes confused or obtunded and unable to follow directions).
   4. Worsening of patient's chest x-ray.
   5. Change in sputum (e.g. increased pulmonary infiltrate, which might indicate need for volume expansion therapy).
   6. Patient has difficulty coughing up secretions, which might indicate need for acetylcysteine and/or bronchial hygiene therapy.

B. Measurement of spirometry or peak flow may be indicated in select patients.

C. In select patients, after initial instruction, MDI therapy may be self administered by the patient or under supervision of the nursing staff.

D. Aerosol Therapy frequency may be tapered as symptoms/indications diminish.

E. Aerosolized medication(s) may be discontinued when goals have been met and patient has been symptom free for 24 hours.

BRONCHIAL HYGIENE THERAPY

PURPOSE:

To open obstructed airways or maintain patent airways in patients at high risk, the respiratory care practitioner will utilize the following protocol to select and initiate bronchial hygiene therapy when indicated.

THERAPEUTIC OBJECTIVES:

To facilitate mobilization of secretions.

INDICATIONS:

A. Aerosol Therapy:
   1. To restore and maintain mucociliary clearance.
   2. To hydrate dried/retained secretions.
   3. To promote expectoration.

B. Percussion/Vibration and Postural Drainage Therapy
   Conditions that require assistance with mobilization of secretions such as bronchiectasis, cystic fibrosis and bronchitis.

STANDARD PROTOCOL:

A. Aerosol therapy will be administered continuously with room air if piped air is available or with 28% oxygen if piped air is not available.

B. Percussion/vibration and postural drainage will be administered QID and PRN.

OUTCOME CRITERIA:

A. Guidelines/Warnings:
   Evaluate patient's clinical status for changes that indicate a need for change in the treatment plan such as:
   1. Change in the patient's sensorium (i.e., confused or obtunded occurring after Rx initiated) may check S_{pO_2} or request ABG.
   2. Significant worsening of dyspnea.
   3. A significant deterioration in patient's chest x-ray.
   4. Increased thickening/production of secretions (e.g. mucolytic therapy may be indicated).
   5. Development of wheezing.
   6. Decreasing S_{aO_2}/S_{pO_2}.
   7. Chest pain
   8. Significant patient discomfort (e.g. increased pain due to percussion therapy).

B. Bronchial hygiene therapy may be tapered as the patient's symptoms/indications diminish.

C. Bronchial hygiene therapy may be discontinued when goals of therapy are met, e.g. secretions easily expectorated for 24 hours, atelectasis is resolved, etc.

PULMONARY VOLUME EXPANSION THERAPY

PURPOSE:

The respiratory care practitioner will utilize the following protocol to select the indicated type of pulmonary volume expansion therapy to prevent or correct pulmonary atelectasis.

THERAPEUTIC OBJECTIVES:

A. Prevent or aid in the treatment of pulmonary atelectasis through periodic lung hyperventilation.

B. Improve mobilization of bronchial secretions by promoting more effective coughing (e.g., increased inspiratory capacity).

INDICATIONS:

A. Incentive Spirometry:
   1. Presence of pulmonary atelectasis.
   2. Restrictive lung defect associated with quadriplegia and/or dysfunctional diaphragm.
   3. Risk for developing pulmonary atelectasis in:
      a. Upper abdominal surgery
      b. Thoracic surgery
      c. Neurosurgical patients

B. Indications for Intermittent Positive Pressure Breathing (IPPB):
   1. Presence of pulmonary atelectasis in patients with VC < 30% of predicted.
   2. Presence of decreased lung compliance in restrictive lung disease, i.e., severe kyphoscoliosis.
   3. Management of impending or worsening hypercapnic respiratory failure, to increase lung expansion.

STANDARD PROTOCOL:

A. Incentive Spirometry—One time instruction followed by nursing encouraged self administration.

B. IPPB—Volume-oriented QID & PRN.

OUTCOME CRITERIA:

A. Guidelines/Warnings
   Evaluate patient's clinical status for changes that indicate a need for change in the treatment plan such as:
   1. A pulse greater than 120 bpm, or if a pulse increase of 20 bpm occurs with bronchodilator medications.
   2. Significant worsening or dyspnea.
   3. Wheezing.
   4. Change in patient's sensorium (i.e. patient now confused or obtunded, and/or unable to follow directions) or decreased patient cooperation.
   5. Significant worsening in patient's chest x-ray or sputum production.
   6. Physician will be called immediately if there is significant worsening of atelectasis, and within 48 hours if no clinical improvement occurs.

B. IPPB frequency may be tapered as the patient's symptoms/indications diminish.

C. IPPB may be discontinued when goals are met or indications are no longer present.

NOTES:

An Operational Evaluation of the Bird Avian Transport Ventilator

Timothy B Op't Holt EdD RRT

BACKGROUND: Mechanically ventilating a patient with a manual ventilator during transport has been known to result in hyperventilation and delivery of inconsistent tidal volumes (V_T) and oxygen concentrations, and hence has led to the development of transport ventilators. I evaluated the Bird Products Avian transport ventilator to determine the ventilator's conformity to criteria established by the American Association for Respiratory Care. DESCRIPTION OF DEVICE: The ventilator is pneumatically powered, microprocessor- controlled, time- or pressure-triggered, pressure-limited, and time-cycled, and can provide breaths in the control, assist/control, SIMV, or CPAP modes. All functions are set by rotating function-labeled knobs. EVALUATION METHODS: Conformity of the ventilator to published guidelines and specifications, V_T delivery at 0.5, 1.0, and 1.5 L and test-lung compliance of 0.02, 0.04 and 0.10 L/cm H_2O, and pressure-trigger and demand-valve responsiveness were evaluated in 2 ventilators borrowed from clinical service, using a test lung and associated software. Alarm functions were also evaluated. EVALUATION RESULTS: V_T and sigh volumes, ventilatory rates, and inspiratory times were consistent between the 2 ventilators tested. The delivered V_Ts varied from −8.8% to +1.2% from the set value. Assist and demand-valve sensitivities were within 1.0 cm H_2O [0.1 kPa] of the set values. With the Ambu PEEP valve attached, expiratory pressures were 11-13 cm H_2O [0.11-0.13 kPa] above baseline. Alarms functioned within specifications. Gas consumption was 3.8 and 6.6 L/min for the 2 ventilators studied. CONCLUSIONS: The Avian conforms to the standards set in the literature and functions within manufacturer's specifications. Assist and demand-valve sensitivities are consistent with that set on the ventilator and are sensitive to simulated patient effort. Gas consumption exceeded manufacturer's specifications in the units tested. Potential exists for increased expiratory work when the Ambu PEEP valve is used. [Respir Care 1996;41(8):714-723]

Introduction

Intra- and interhospital transport of mechanically ventilated patients is a common event and predates the invention and use of transport ventilators. Critically ill, ventilator-dependent patients are often transported to magnetic resonance imaging, computerized tomography, or radionucleotide imaging suites, distant from the intensive care unit. Ventilation of the patient during these transports has been accomplished through the use of manual ventilators and/or portable transport ventilators. Several studies have examined the blood gas and hemodynamic consequences of ventilation via manual ventilator and use of portable ventilators during transport.[1-4] Other studies have evaluated the effectiveness of transport ventilators, both in the laboratory and in the clinical setting.[5-8] In addition, the American Association for Respiratory Care (AARC) has published a Consensus Statement on the Essentials of Mechanical Ventilators—1992[9] and a Clinical Practice Guide-

Dr Op't Holt is Associate Professor, Cardiorespiratory Sciences Program, College of Allied Health Professions, University of South Alabama, Mobile, Alabama.

The author has no financial interest in any of the devices or products presented in this paper or in competing products.

Correspondence: Timothy B Op't Holt, 1504 Springhill Ave, Mobile AL 36604, email address: toptholt@jaguar1.usouthal.edu.

line: Transport of the Mechanically Ventilated Patient,[10] which suggest additional evaluation criteria.

To my knowledge, this study is the first published evaluation of the Avian transport ventilator,* designed for intra-hospital, field, and aeromedical ventilation of children and adults. The device and its conformity with the AARC Consensus Conference Statement and AARC Clinical Practice Guideline are described and the results of operational and laboratory evaluations reported.

Description of Device

The Avian ventilator (Fig. 1) is a pneumatically powered, microprocessor-controlled, time- or pressure-triggered, pressure-limited, and time-cycled ventilator. Specifications and alarm and monitoring functions are shown in Table 1.

Pneumatic System

Figure 2 shows that gas enters the ventilator and flows to a pressure-reducing valve, where pressure is reduced to 30 psi. This provides a stable operating pressure for the remaining internal components, a stable tidal volume (V_T), and a reliable demand flow, even if inlet pressure fluctuates. Gas enters the main solenoid valve, which controls the flow of gas for mandatory breaths. At the beginning of inspiration, this valve opens and gas flows through the flow-control valve, which regulates the flow to the operator-set value. The flow-control poppet attached to the flow-control valve senses the position of the valve and sends this information to the microprocessor for calculation and display of the inspiratory V_T. Flow continues through the check valve and out of the ventilator into the circuit. At the end of inspiration, the main solenoid closes. During inspiration, the exhalation valve balloon is inflated by gas at a pressure that is generated upstream from the check valve. At the end of inspiration, the exhalation valve balloon gas is bled-off at the orifice. During a spontaneous breath in the synchronized intermittent mandatory ventilation (SIMV) or continuous positive airway pressure (CPAP) modes, the demand solenoid valve opens in response to the patient's inspiratory effort. Gas flow from the regulator and demand solenoid valves is regulated up to 100 L/min in response to patient demand and flows through the check valve to the patient. Gas not used by the patient is vented to atmosphere because the exhalation valve is not closed during a spontaneous breath. Demand flow stops to allow exhalation when proximal airway pressure rises above the reference baseline. The pressure-relief valve is a safety feature during volume ventilation and may be used to deliver pressure-limited breaths. Should airway pressure exceed the pressure-relief-valve setting, excess gas is vented to the atmosphere, while pressure is held constant at the relief pressure. In the event of ventilator failure, the patient can breathe from the environment through the anti-

*Suppliers of commercial products are listed in the Product Sources section at the end of the text.

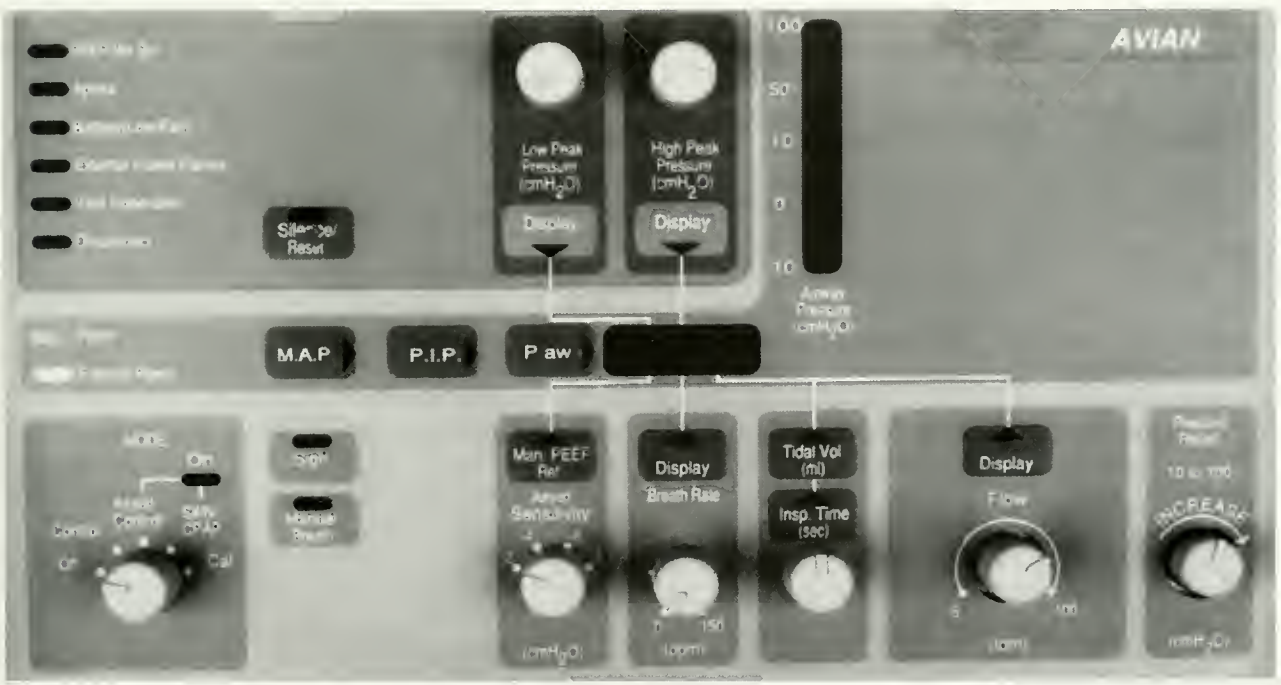


Fig. 1. Control panel of the Bird Products Avian ventilator.

Table 1. General Specifications for the Avian Transport Ventilator

Weight	5.0 kg
Dimensions	25.4 cm (L) × 30.5 cm (W) × 12.7 cm (H)
Power Sources	
External	110-volt alternating current 12-volt direct current (automobile battery) External power indicator
Internal	6-volt direct-current, rechargeable internal battery (up to 11 hours) Low-fail indicator illuminates about 1 hour prior to failure; audible alarm when voltage drops below 3.96 volts DC
Gas Source	Requires 40-60 psi source; reducing valve reduces to 30 psi Ventilator supplies 100% source gas; blender required to provide other O_2 concentrations.
Control Variables & Ranges	
Rate	0-150 breaths/min
Inspiratory time	0.1 -3.0 s
Tidal volume	50-2000 mL
Oxygen concentration	100% source gas
Modes	Controlled, assisted, synchronized intermittent, continuous positive airway pressure
Inspiratory flow	5-100 L/min
Sensitivity	−2 to −8 cm H_2O [−(0.2-0.87) kPa]
Sigh	1.5 × V_T or T_I, every 100 breaths, or 7 minutes
PEEP	External valve, 0-20 cm H_2O [0-1.96 kPa]
Pressure relief	10-100 cm H_2O [0.98-9.8 kPa]
Alarm & Monitoring Functions & Ranges	
Alarm	Range
High peak pressure	1-100 cm H_2O [0.1-9.8 kPa]
Low peak pressure	Off, 2-50 cm H_2O [0.2-4.9 kPa]
Inspiratory-to-expiratory time ratio	T_I > 50% total cycle time
Apnea	2 breaths > 20 s apart
Disconnect	Pressure increase < 2 cm H_2O [0.2 kPa]
External power low/fail	External voltage out of range
Battery low/fail	Battery voltage out of range
PEEP not set	Monitored PEEP ±5 cm H_2O[0.49 kPa] from manually set PEEP
Airway pressure monitor	−10 to 100 cm H_2O [−0.98-9.8 kPa]
Peak inspiratory pressure	0-100 cm H_2O [0-9.8 kPa]
Mean airway pressure	0-100 cm H_2O [0-9.8 kPa]
Airway pressure	0-100 cm H_2O [0-9.8 kPa]

V_T = tidal volume, T_I = inspiratory time, PEEP = positive end-expiratory pressure.

suffocation valve. Proximal airway pressure is measured and converted to an electrical analog signal by the airway pressure transducer. This pressure is used for the bar graph display, breath triggering, and the pressure alarms.

Modes

The mode in use is determined by the mode-selection knob. In the event of an apneic interval longer than 20 seconds during CPAP, the apneic ventilation function is activated to provide ventilation at a rate of 12 breaths/min at the set V_T or inspiratory time (T_I) and flow.

Controls

All functions are set by rotating function-labeled knobs shown in Figure 1. Whenever the adjacent key is pressed, the value for that function illuminates in the digital display window, and any time a knob is turned, the value for that variable is immediately displayed in the display window. The pressure-relief valve is set so that the pressure-relief valve is not activated during delivery of a normal V_T. Because the level at which pressure is relieved is not digitally displayed, the user must occlude the patient connection, monitor peak inspiratory pressure (PIP), and observe the display window to check relief pressure. Airway pressure is monitored at the proximal airway and displayed on the bar-graph indicator; and in the display window when either PIP or airway pressure (P_{aw}) keys are pressed. T_I, V_T, flow, and rate interact.

PEEP System

Positive end-expiratory pressure (PEEP) is supplied by an external PEEP valve. Under normal circumstances, PEEP compensation occurs automatically through airway pressure monitoring. (ie, PEEP compensation is the ventilator's ability to maintain sensitivity to patient inspiratory effort as the baseline pressure, PEEP, is increased or decreased.) PEEP compensation may also be set manually via the manual PEEP-reference function. When the operator depresses the manual PEEP-reference button for longer than 3 seconds, the digital display scrolls from 0-20 cm H_2O. When the button is released, the value shown in the display window becomes the PEEP reference. Inspiratory pressure-trigger sensitivity may be set in increments of 2 cm H_2O [0.2 kPa] from −2 to −8 cm H_2O [−0.2 to −0.78 kPa] below baseline.

Patient Circuit

The patient circuit and gas supply connect to the front of the ventilator. Although the ventilator is supplied with a reusable circuit, disposable circuits are available. The patient circuit consists of a 4-piece patient valve that has a balloon-type exhalation valve, connections for the exhalation valve line and airway pressure monitoring line, and a 15/22-mm patient connection. Connecting the patient valve to the ventilator are a large-bore corrugated tubing for gas delivery and two 1/8″ tubes for the exhalation valve and pressure monitor. A high-pressure hose is provided to connect the ventilator to a blender

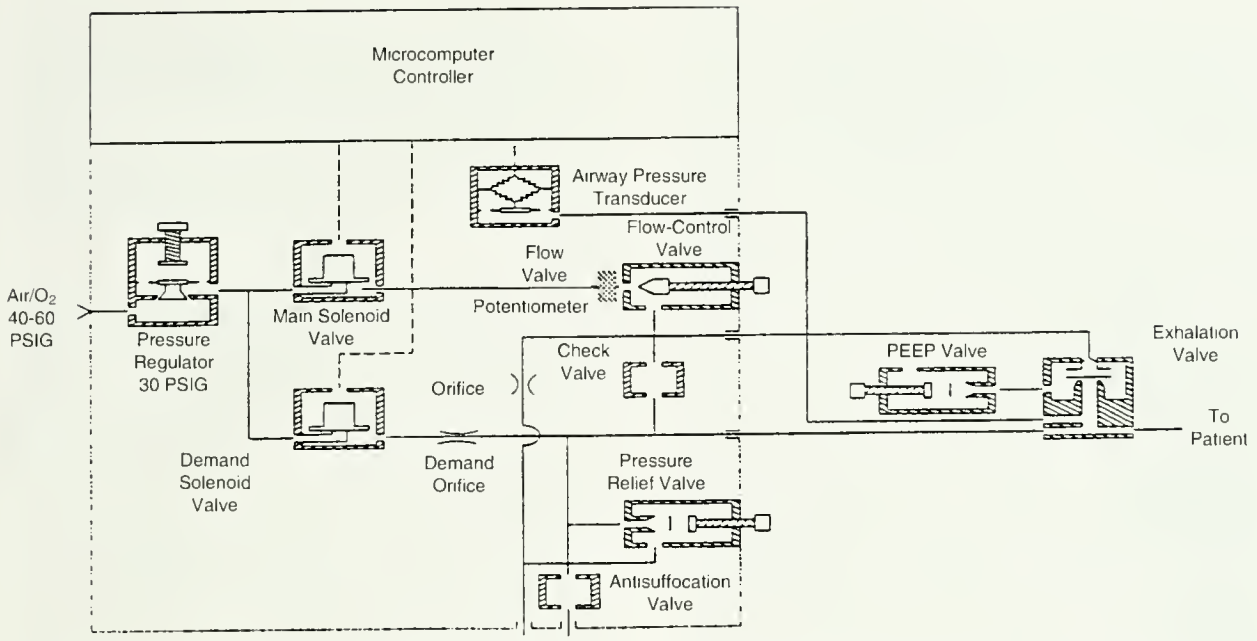


Fig. 2. Diagram of Bird Products Avian ventilator. PEEP = positive end-expiratory pressure, PSIG = pounds per square inch gauge. (Courtesy of Bird Products Corp, Palm Springs CA)

or other gas source. Adjacent to the circuit connections is the external power jack.

Application of the Device

The ventilator is intended for use in clinical, field hospital, aeromedical, and transport situations. It is designed for use on adults and for children with V_Ts as low as 50 mL and T_Is as short as 0.1 second. No circuit specifically for pediatric use has been recommended by the manufacturer although any circuit with low compressible volume and external exhalation valve should be acceptable. The circuit supplied with the ventilator has a compliance of 0.42 mL/cm H_2O and is probably suitable for pediatric use. The ventilator is not compatible with magnetic resonance imaging because of its metallic components, and pressure support is not available.

Before the patient is connected to the ventilator, the mode knob is placed in the CAL position. During CAL, the microprocessor illuminates all light-emitting diodes and monitors the airway pressure transducer output. If all checks are within range, PASS appears in the display window. Any test out of range results in a FAIL display, and the ventilator should not be used. Once calibration is complete, the user continues by setting controls.

Methods

Testing Criteria

The AARC Consensus Statement issued in 1992[10] categorizes ventilator features as essential, recommended, or optional. I used those categories and the criteria in the transport ventilator Clinical Practice Guideline[9] and those in similar studies.[5,8] Two Avian ventilators that had been in clinical use were provided for this study by the manufacturer's representative. All tests were performed on both ventilators, (referred to as V1 and V2). Data were reported as means and standard deviations.

Operational Evaluation

The ventilator was tested to determine (1) its ability to deliver a set V_T when test-lung compliance (C_{TL}) was varied, (2) pressure trigger sensitivity for mandatory breaths, (3) pressure changes produced during CPAP, (4) accuracy of rate and inspiratory time and sigh interval and volume, (5) alarm function, (6) battery life, and (7) gas consumption. The ventilator was set up according to manufacturer's specifications.[11] The ventilator's pressure transducer was calibrated by positioning the mode knob in the CAL position for 3 seconds, until the PASS message illuminated. This process zeros the transducer and allows the ventilator to compensate for thermal and long-term drift from zero baseline.

All volumes, pressures, and times were measured by the Michigan Instruments Training Test Lung (TTL) and its data acquisition software, PneuView V2.2, which is the software link between the TTL and computer (personal computer with a 486 processor). The test lung has been used for several years for the purposes of simulating a breathing lung, and for ventilator testing, instruction, demonstration, research, and engineering. The software requires a hardware modification to the

test lung consisting of three pressure transducers: one for each lung, and one for the proximal airway pressure.

Pressure signals are sampled at a rate of 100/s, converted from analog to digital values, converted to cm H_2O, and then digitally displayed. Volumes are determined by taking the measured pressure values and submitting them to electronic volume tables. Volume tables are created by the manufacturer by making 24 injections of volume ranging from 20 to 2,000 mL at each C_{TL} on 10 different TTL devices, for a total of 3,600 injections. These tables are part of the software, and all were updated for Version 2.2. Before starting a test run, the user enters a reference compliance that is the same as the C_{TL}. When a pressure is measured for a given C_{TL}, a V_T results ($P \times CTL = V_T$). This V_T is corrected for temperature and barometric pressure, both of which are set by the user as reference conditions in the software. This results in the displayed V_T. The software determines volumes in the range of 0.1 to 4.0 L. The V_T divided by the T_I from the computer's clock results in the displayed flow, which is corrected for resistance, an additional user-set reference value. Airway resistance is changed by placing adapters of known resistance between the ventilator being tested and the test lung. The software has options for waveform analysis on a breath-to-breath basis, trending of ventilator performance, and a translator program to allow translation of tabulated data into ASCII format for conversion to spreadsheet programs. Any of the data captured by the software can be graphically displayed on the computer screen or printed.

To calibrate the TTL, pressures were calculated for each compliance used (20, 40, and 100 mL/cm H_2O) at 500 and 1,000 mL ($P = V/C$). The pressure transducers were zeroed using the offset potentiometer on the back panel of the test lung. A volume of air (500 or 1,000 mL) was injected using a 1.0-L calibration syringe, and the pressure transducer was calibrated to the predicted pressure, using the gain potentiometer on the back panel of the test lung. The test lung was also checked for leaks before testing by the injection of 1.0 L at a C_{TL} of 0.02 mL/cm H_2O, a procedure expected to produce a pressure that should not drop by more than 1.0 cm H_2O in 30 seconds. Once the test lung and software are calibrated, and reference values for compliance, resistance, temperature, and barometric pressure are entered, the system is ready for ventilator testing.

V_Ts and C_{TL} were set as described by Johannigman et al;[8] however, the use of the TTL with the PneuView program is a new methodology introduced in this report. Ventilator rate was set to 12 breaths/min and flow to 60 L/min, with C_{TL} set of 100 [9.8], 40 [3.9], and 20 mL/cm H_2O [1.9 kPa] for V_T of 500, 1,000, and 1,500 mL. The Rp-5 resistor, supplied by the manufacturer of the test lung, was placed between the proximal pressure tap and the 'trachea,' to simulate normal airway resistance. All measurements were for 1 minute. Comparisons were made based upon 10 consecutive breaths.

Sigh volume (V_{sigh}) and rate were tested by using the ventilator-performance trending capability of the software. V_T was set at 800 mL, flow at 60 L/min, and rate at 20 breaths/min, which should result in a 1,200-mL V_{sigh} every 5.0 minutes (every 100 breaths). V_{sigh} was tested at C_{TL}s of 100 [9.8 kPa], 40 [3.9 kPa], and 20 mL/cm H_2O [1.9 kPa]. Sigh frequency was checked by observing the time interval between each sigh.

Accuracy of time-triggered ventilator rate was checked at 10, 25, 50, 100, and 150 breaths/min by setting the desired rate on the ventilator and observing the measured rate with the software. Accuracy of T_I was checked at 0.2, 0.5, 1.0, and 1.5 seconds by observing actual T_I as digitally displayed.

Pressure-trigger sensitivity for mandatory breaths was tested by setting the trigger sensitivity at –2.0 and –4.0 cm H_2O [–0.2 and –0.4 kPa] with a V_T of 500 mL and a rate of 15 breaths/min and connecting the ventilator to the right lung of the TTL. Spontaneous inspiratory efforts were simulated by the left side of the test lung ventilated by a Bear-1 ventilator set at a rate of 15 breaths/min, inspiratory flow 50 L/min, and V_T of 200 mL to lift the right lung using the lung-coupling clip supplied by the test lung manufacturer. Actual pressures at which volume delivery commenced were recorded and means (SD) calculated.

Pressure changes produced during CPAP were analyzed by setting CPAP levels of +5 [0.5], +10 [0.98], and +15 [1.5] cm H_2O [kPa] and recording the actual negative pressure at the pressure output of the test lung at the time of triggering and by observing the changes in the pressure pattern throughout inspiration following the initiation of the breath. PEEP compensation was allowed to set automatically. Sensitivity was set at –2.0 [–0.2] and –4.0 [0.4 kPa]. Spontaneous breathing was simulated by ventilating the left side of the test lung with a Bear-1 ventilator at V_T 400 mL, rate 15 breaths/min, peak inspiratory flow 50 L/min, and square-wave flow pattern.

The low-pressure alarm was tested by setting it to 2 cm H_2O [0.2 kPa] below the peak pressure, then allowing the peak pressure to fall by 2 cm H_2O [0.2 kPa]. The high-pressure alarm was tested by setting it to 2 cm H_2O [0.2 kPa] above peak pressure and then compressing the test lung to cause a pressure of 2 cm H_2O [0.2 kPa] above peak. The apnea alarm was tested by setting the ventilator in the CPAP mode and withholding 'spontaneous' breaths.

Battery life was checked by charging the battery overnight and then setting the ventilator in the control mode with $V_T = 600$ mL, rate = 12 breaths/min, and flow = 60 L/min. The ventilator was then operated until the Low-Power light illuminated.

Ventilator gas consumption was determined by subtracting the amount of gas used to provide minute volume, or $\dot{V}_E$ ($V_T \times f \times$ length of test in minutes) from the total gas consumed (pressure change in the K cylinder $\times$ 3.14), yielding the ventilator gas consumption. The ventilator gas consumption was divided by the number of minutes of the test, yielding the ventilator gas consumption in L/min:

ventilator gas consumption =

$$\frac{[(\text{gas pressure change} \times 3.14) - (\dot{V}_E \times \text{minutes of test})]}{\text{minutes of test.}}$$

The manufacturer's specifications state that gas consumption is 2-3 L/min beyond that for $\dot{V}_E$.

Results

V_Ts delivered to the circuit-test lung system are shown in Table 2 and were both higher and lower than the set V_Ts, varying from −8.8 to 1.2% from the set V_Ts. V_{sigh}s (specified to be 1.5 times the V_T, or 1.2 L in this study) are supplied in Table 2. Sigh frequency was 1 sigh every 5 minutes.

Table 2. Measured Tidal Volumes* at 3 Set Tidal Volumes and Test-Lung Compliances (C_{TL}) and Sigh Volumes at Those Compliances, Uncompensated for Tubing Compliance

	Test Ventilator	Set C_{TL} (mL/cm H_2O) [mL/0.98 kPa] 20	40	100
Set V_T (mL)				
500	V1	470.6 (4.2)	456.3 (1.3)	460.8 (1.5)
	V2	492.7 (5.4)	466.5 (2.6)	470.8 (1.9)
1000	V1	1,001.3 (8.5)	966.1 (3.6)	983.7 (2.7)
	V2	969.4 (1.4)	982.1 (1.7)	969.4 (1.4)
1500	V1	1,528.6 (2.0)	1,469.3 (1.7)	1,460.8 (1.8)
	V2	1,510.1 (5.0)	1,445.0 (5.0)	1,464.0 (9.0)
Set V_{sigh} (mL)				
1200	V1	1,186	1,180	1,227
	V2	1,116	1,165	1,129

* Values reported for tidal volumes (V_Ts) are mean (SD) for 10 breaths. V_{sigh} = sigh volumes.

The actual ventilator rates at set rates of 10, 25, 50, 100, and 150 breaths/minute were 9.9, 24.8, 49.6, 98.4, and 146.3, respectively. There were no differences between ventilators. Actual inspiratory times for set inspiratory times of 0.2, 0.5, 1.0, and 1.5 seconds were 0.25, 0.51, 1.01, and 1.52 seconds, respectively. There were no differences between ventilators.

The mean (SD) sensitivity of the inspiratory pressure-triggering mechanism during 10 breaths in the assist/control mode was −1.95 (0.14) cm H_2O for V1 and −2.14 (0.13) for V2 when set at −2 cm H_2O, and 3.5 (0.22) cm H_2O for V1 and −3.59 (0.16) for V2 when set at −4 cm H_2O. Pressure changes during CPAP on sensitivity are shown in Table 3 and Figure 3.

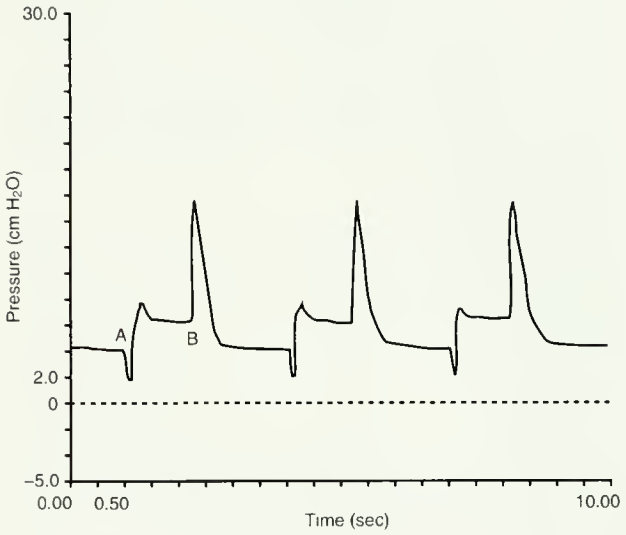


Fig. 3. Pressure curve at 5 cm H_2O [0.49 kPa] continuous positive airway pressure (CPAP). From the set CPAP level, following the inspiratory effort (A), pressure plateaus throughout inspiration. At end inspiration (B), the patient must overcome the resistance of this particular brand of positive end-expiratory pressure valve, evidenced by the spike which exceeds a pressure of 10 cm H_2O [1.0 kPa] above CPAP.

Low-pressure, high-pressure, and apnea alarm functions operated according to manufacturer's specifications. When the airway pressure dropped below the set limit (2 cm H_2O below PIP), the Low-Pressure alarm sounded and the Low-Pressure indicator illuminated. However, at the set limits with an inspiratory flow of 70 L/min and V_T 500 mL, decreasing the V_T to 100 mL did not decrease the proximal airway pressure enough to trigger the alarm. The Low-Pressure alarm did sound within 1 breath of disconnection. When airway pressure exceeded the set limit (2 cm H_2O above PIP), the alarm

Table 3. Set and Actual Demand-Valve Sensitivities at 5, 10, and 15 cm H_2O [0.49, 0.98, and 1.47 kPa] of Continuous Positive Airway Pressure (CPAP) for 2 Test Ventilators (V1 & V2).

	CPAP 5 cm H_2O		CPAP 10 cm H_2O		CPAP 15 cm H_2O	
Set Pressure	−2	−4	−2	−4	−2	−4
Actual Pressure						
V1	−2.6 (0.17)*	−2.74 (0.25)	−2.62 (0.16)	−2.74 (0.19)	−2.90 (0.18)	−2.30 (0.21)
V2	−1.9 (0.15)	−3.69 (0.15)	−1.65 (0.78)	−2.18 (0.15)	−2.28 (0.16)	−2.34 (0.17)

* Values are mean (SD).

sounded and the High-Pressure indicator illuminated. In the CPAP mode, when spontaneous breaths were withheld for 20 seconds, the apnea alarm sounded, the visual apnea alarm flashed, and the ventilatory rate became 12 breaths/min.

The design of the ventilator is such that when gas supply is less than 40 psi, an antisuffocation valve opens during inspiration, denoted by a honking sound. When the gas supply pressure fails completely, the ventilator delivers gas that has remained in the pneumatic circuit. The patient may then breathe spontaneously through the antisuffocation valve. In both cases, as soon as PIP fell to the low pressure limit, the Low-Pressure alarm sounded.

The ventilators were operated for 14 hours at V_T 600 mL, rate of 12, and flow of 60 L/min. After 14 hours, the alarm sounded with each breath and the Battery-Fail light illuminated. After 16 hours, the alarm sounded continuously. The test was discontinued at 16.5 hours, to avoid exhausting the batteries. During this period, the ventilators continued to deliver the set rate and V_T.

Each ventilator was operated for just over 3 hours to determine ventilator gas consumption. Other than the gas that was used to ventilate the test lung, the V1 required 3.8 L O_2/min and V2 required 6.6 L O_2/ min to operate the internal circuits and valves. This represents a 127-220% increase over the manufacturer's specification.

The Avian conforms to most recommendations and standards of the AARC Consensus Statement and the Clinical Practice Guideline for transport ventilators as illustrated in Tables 4-6.

Table 4. Conformity of the Avian Ventilator to Recommendations in AARC Clinical Practice Guideline: Transport of Mechanically Ventilated Patients[9]

Recommendation	Avian Conforms?
Independent control of tidal volume	Yes
Independent control of respiratory frequency	Yes
Provides continuous mechanical ventilation in	
Assist/control mode	Yes
Intermittent mandatory mode	Yes
Delivers constant volume in the face of changing pulmonary impedance	Yes
Monitors airway pressure	Yes
Provides a disconnect alarm	Yes
Provides PEEP (with ancillary PEEP valve)	Yes
Provides 100% oxygen (precise control with blender)	Yes

PEEP = positive end-expiratory pressure.

It has been recommended that the transport ventilator weigh ≤ 5 kg, controls be on the same plane, dimensions facilitate post mounting or placing on the bed, and control knobs be difficult to change inadvertently.[10] The Avian meets these recommendations.

It is recommended that circuit assembly be easy and misassembly impossible. The patient connection consists of 4 pieces that cannot be improperly assembled. The 3 tubes—gas delivery, proximal airway pressure, and exhalation valve—have fittings that cannot be interchanged at the ventilator. Proximity of the 3 connections to the ventilator and the location of the handle causes the connection of the 3 tubes to the ventilator to be difficult for someone with large hands. It is recommended that the ventilator have a pressure-relief valve, antiasphyxia valve, low-battery indicator, and loss-of-gas-source alarm.[10] The Avian has these features except that the gas source loss is not directly measured.

Discussion

During intrahospital transport of critically ill patients, hypotension, cardiac arrhythmias, hypoxemia, hyper- and hypoventilation, and acidemia or alkalemia may occur. Several investigators have studied the occurrence of these complications during transport while the patient was either being manually ventilated or ventilated with one of several portable transport ventilators. In Hurst et al's study,[1] all patients showed a marked respiratory alkalosis following transport with a manual ventilator, while the same patients ventilated with the transport ventilator displayed no alkalosis. Likewise in the study by Braman et al[3] and Gervais et al,[2] arterial blood-gas values in patients transported with a manual ventilator demonstrated alkalosis caused by "overzealous use" of the manual ventilator. However, both Gervais et al[2] and Weg et al[4] showed that if the manual ventilator operator maintained the patient's minute ventilation equal to that before transport, no significant changes in blood gas values developed. In my experience, undivided attention to manual ventilation is difficult because one must also pay attention to getting the patient's bed through doorways, into elevators, and through crowded corridors, while avoiding the dislodging of catheters and other tubes. Each of the authors[1-4] agrees that the use of a transport ventilator is effective in appropriately maintaining the patient's blood gas values. However, the use of a transport ventilator has not become a standard of care in the same sense that pulse oximetry seems to have become an essential element of monitoring critically ill patients.

Several studies have focused on the performance characteristics of available portable ventilators. Prominent in these studies were measurements of delivered V_T. In the study by Campbell and colleagues[5] of the Impact Uni-Vent 750, V_T decreased insignificantly as compliance decreased from 100 to 20 mL/cm H_2O [1.0 to 0.20 kPa]. A significant decrease in V_T as compliance decreased was documented by Johannigman et al's evaluation[8] of the Hamilton MAX ventilator. Results are similar for other ventilators tested; the decrease in V_T varied widely by ventilator model.[6,7] Also included in these reports were evaluations of demand-valve sensitivity with and without PEEP, alarm performance, and the ventilator's ability to maintain arterial blood gases in a selected group of patients.

Table 5. Conformity of the Avian Ventilator to Criteria Established by AARC Consensus Statement on the Essentials of Mechanical Ventilators—1992[10]

Feature	Status			Avian Conforms?
	Essential	Optional	Recommended	
Control				
	Positive pressure tidal breaths			Yes
	Mandatory rate			Yes
	PEEP			Yes
		Flow, I:E, or T_I control		Yes
	F_{DO_2} (with blender)			Yes
			Spontaneous breathing modes	Yes
			Breath triggering mechanism	Yes
		PSV or MMV		No
Monitoring				
	Peak pressure			Yes
		Mean airway pressure		Yes
		Plateau pressure		Checked by circuit occlusion
	PEEP			Yes
		Intrinsic PEEP		No
			Exhaled V_T	No
		Machine $\dot{V}_E$		No
			Exhaled spontaneous V_T	No
		Spontaneous $\dot{V}_E$		No
			Inspired spontaneous V_T	No
		Flow timing		No
		Spontaneous flow		No
			I:E	Can be calculated
			Rate	Yes
			Lung mechanics	No
			Tubing compliance	No

PEEP = positive end-expiratory pressure, T_I = inspiratory time, F_{DO_2} = fraction of delivered oxygen, PSV = pressure support ventilation, MMV = mandatory minute ventilation, V_T = tidal volume, $\dot{V}_E$ = expired volume/minute, I:E = inspiratory-to-expiratory ratio.

Table 6. Conformity of the Avian Ventilator to Recommendations for Ventilator Alarms Established by AARC Consensus Statement on the Essentials of Mechanical Ventilators—1992[10]

Event		
Level 1 Immediately Life Threatening	Level 2 Potentially Life Threatening	Avian Conforms?
Power failure		Yes
Absence of gas delivery (apnea)		Yes
Loss of gas source		Low-pressure alarm
Excessive gas delivery		No
Exhalation valve failure		Low-pressure alarm
	Battery power loss	Yes
	Circuit leak	Yes
	Blender failure	Low-pressure alarm
	Partial circuit occlusion	Yes
	Heater/humidifier failure	Not applicable
	Loss of or excessive PEEP	No
	Autocycling	If PEEP reference not set

PEEP = positive end-expiratory pressure

Since publication of the reports mentioned and others on the hazards of intrahospital transport and transport ventilator evaluation, the AARC has published the Consensus Statement on the Essentials of Mechanical Ventilators, "with the intent of providing clinicians with the information necessary to make informed decisions regarding the purchase and operation of mechanical ventilators and to assist manufacturers in the development of devices that best serve the patient and clinician."[10] In addition, the AARC has made recommendations in the Clinical Practice Guideline: Transport of Mechanically Ventilated Patients.[9] Within the Guideline is a list of hazards to avoid and desirable equipment characteristics to consider when intrahospital transport is anticipated. My evaluation tested the consistency of the Bird Avian ventilator with the Consensus Statement and the Guideline, using a format similar to that used in the reports of Campbell et al[5] and Johannigman et al.[8]

As shown in Table 4, the Avian complies with recommendations in the Transport Guideline.[9] Although impedance was not measured, no clinically important change in tidal or sigh volume was observed as C_{TL} was decreased. PEEP is not an integral control on the ventilator, but a PEEP valve is provided by the manufacturer. The ventilator is designed to be

connected to a 50 psi air-oxygen blender for oxygen concentration control from 0.21-1.0, but O_2 delivery was not evaluated. The ventilator conforms to most of the AARC Consensus Conference recommendations.[10] The ventilator does not monitor several of the variables monitored by third-generation adult ventilators, such as intrinsic PEEP, lung mechanics, and tubing compliance, but the risk associated with not monitoring them during transport may be low and the cost associated with providing them may not be warranted. The absence of an alarm specifically for loss of gas pressure may be important because several other malfunctions can cause the low-circuit-pressure alarm to sound. Loss of source-gas pressure is probably more likely on a transport ventilator than on one connected to a central source.

The ventilator should withstand a drop to the floor—continuing to operate or allowing ventilation through the anti-suffocation valve—but this was not evaluated. It is possible that settings could change in a high-vibration environment such as a helicopter or ambulance, but the tension on each control knob would seem to make such an accidental change unlikely.

During the evaluation, I found the ventilator easy to set up and operate with a minimum need for study.

Operational Evaluation

Delivered V_Ts tended to be less than the V_T set, but the differences are probably not clinically important (−8.8 to +1.2%) and appear to be independent of C_{TL}. Volumes determined by the PneuView program include the volume in the ventilator circuit and the test lung. To determine only the test-lung volume (a volume adjusted for circuit compliance), one multiplies the circuit compliance by the PIP and subtracts this product from the total delivered V_T. Therefore, the less compliant the circuit, the more volume actually delivered to the patient. However, the purpose of this study was to determine total delivered volume, rather than the volume adjusted for tubing compliance. The compliance of the reusable circuit supplied with the ventilator is 0.42 mL/cm H_2O. The differences between set and delivered volumes for the Avian are ≤ the differences reported for other transport ventilators.[5-8] V_{sigh}s varied from −35 to +29 mL (< 3%) from the expected value. Differences between ventilators may be due to (1) intrinsic variation in the ventilators or in the internal calibration or (2) differences in PIP and, therefore, in the volumes calculated by the software program. Practitioners should verify the exhaled V_T with a respirometer or similar device and make the necessary volume adjustment before proceeding with the transport.

Gas consumption varied between the 2 ventilators (3.8 L/min for V1 and 6.6 L/min for V2). In unreported work, I used the same formula but a different pressure-reducing valve, and noted the gas consumption of 2 other Avian ventilators to be 4.2 and 3.0 L/min, for an average from the 4 units of 4.4 L/min (147% of the manufacturer's specification).This increased gas consumption could be due to an internal leak in the ventilator and/or inaccuracy of readings from the pressure-reducing valve, or nonlinearity of the pressure-reducing valve. Periodic measurement of gas consumption may be a desirable (and prudent) part of the operational verification procedure.

Trigger sensitivity is within 1.0 cm H_2O of the set value, which is similar to the Uni-Vent[5] and superior to the MAX.[8] As PEEP was increased, trigger sensitivity decreased by only 0.32 for V1 and 0.63 cm H_2O for V2, demonstrating that the PEEP compensation mechanism functioned appropriately. The negative-pressure deflection at the onset of the inspiratory effort is due to the sensitivity of the trigger mechanism. This deflection lasts 0.1 to 0.2 second and is followed immediately by gas delivery at or above the set trigger-sensitivity level. The variation in the pressure at baseline during inspiration as PEEP increases is caused by the response of the demand valve to lung-model 'inspiratory effort' throughout the breath. Changes in airway pressure during this phase are negligible. This performance is consistent with the Uni-Vent and better than that of the MAX because the MAX offers no PEEP compensation.

Expiratory pressure above baseline with PEEP varied from 11.0 to 13.0 cm H_2O [1.1 to 1.3 kPa] above baseline. These data may be clinically significant, as the expiratory work of breathing may increase because the patient must exert this opening pressure in order to exhale. Ideally, the expiratory pressure would be at baseline. This expiratory pressure is a function of the Ambu PEEP valve, rather than the Avian ventilator. In the Ambu PEEP valve, the patient must overcome the resistance of the spring that seals the expiratory orifice. Other PEEP valves may have a lower expiratory pressure.[12] This resistance causes a prolonged (0.8-1.2 s) active portion of expiration, which if the patient's ventilatory rate increased could lead to auto-PEEP. Campbell notes in his review of the Uni-Vent that the manual PEEP reference is useful for tachypneic patients or for high-vibration environments such as a helicopter.[5]

I did not measure the ventilator's ability to ventilate the test lung with increasing respiratory impedance or at extremes of V_T and rate. Use of the ventilator with > 15 cm H_2O of PEEP was not evaluated because 15 cm H_2O is the limit of the PEEP valve provided. I did not compare blood gas values in human subjects ventilated by ICU ventilators and by the Avian.

The ventilator was recalled by the manufacturer in 1996 after carbon deposits were found adjacent to the capacitor that energizes the alarm system. Apparently some arcing had occurred due to an oxygen leak within the ventilator housing. All ventilators were inspected and modified as necessary, with most ventilators now returned to clinical service.[†]

[†] Don Loewel, Avian Product Manager, Bird Products Corporation, facsimile describing recall and remedy, March 29, 1996: Personal Communication.

Conclusions

The Bird Avian transport ventilator conforms to the standards set in the literature for operational, monitoring, and alarm features of transport ventilators. The only alarm that is not present but desirable, is that for loss of source gas. Gas consumption exceeds manufacturer's specifications and varies from unit to unit. Further study could be conducted to determine ease of clinical use, ability to maintain blood gas values, and the need for additional monitors and alarms.

PRODUCT SOURCES

Calibration Syringe:
PN113091-5540, 1.0 L, reverse markings and low dead space, Hans Rudolph Inc, Kansas City MO

PEEP Valve:
Ambu Inc, Linthicum MD

Test Lung:
Dual Adult TTL, Michigan Instruments Inc, Grand Rapids MI

Ventilators:
Bear-1, Allied Health Care Products, Riverside CA
Avian, Bird Products Corp, Palm Springs CA

Data Acquisition Software:
PneuView V2.2, 1996: Michigan Instruments, Grand Rapids MI

Statistical Software:
Excel V5.0, 1993: Microsoft Inc, Redmond WA

REFERENCES

1. Hurst JM, Davis K, Branson RD, Johannigman JA. Comparison of blood gases during transport using two methods of ventilatory support. J Trauma 1989;29(12):1637-1640.
2. Gervais HW, Eberle B, Konietzke D, Hennes HJ, Dick W. Comparison of blood gases of ventilated patients during transport. Crit Care Med 1987;15(8):761-763.
3. Braman SS, Dunn SM, Amico CA, Millman RP. Complications of intrahospital transport in critically ill patients. Ann Intern Med 1987; 107(4):467-473.
4. Weg JG, Haas CF. Safe intrahospital transport of critically ill ventilator-dependent patients. Chest 1989;96(3):631-635.
5. Campbell RS, Davis Jr K, Johnson DJ, Porembka D, Hurst JM. Laboratory and clinical evaluation of the Impact Uni-Vent 750 portable ventilator. Respir Care 1992;37(1):29-36.
6. Nolan JP, Baskett PJF. Gas powered and portable ventilators: an evaluation of six models. Prehospital and Disaster Medicine 1992;7(1): 25-34.
7. McGough EK, Banner MJ, Melker RJ. Variations in tidal volume with portable transport ventilators. Respir Care 1992;37(3):233-239.
8. Johannigman JA, Branson RD, Campbell R, Hurst JM. Laboratory and clinical evaluation of the MAX transport ventilator. Respir Care 1990;35(10):952-959.
9. American Association for Respiratory Care. Clinical practice guideline: transport of the mechanically ventilated patient. Respir Care 1993;38(11):1169-1172.
10. American Association for Respiratory Care. Consensus statement on the essentials of mechanical ventilators. Respir Care 1992;37(9): 1000-1008.
11. Bird Avian Operator's/Service manual. Bird Products Corporation, August 1993.
12. Banner MJ. Expiratory positive-pressure valves: flow resistance and work of breathing. Respir Care 1987;32(6):431-439.

Bench Evaluation of the ServO$_2$ Oxygen-Control System

Frank Dennison MEd RRT RPFT, D Spencer Brudno MD, David Lain PhD JD RRT, and Vladimir Kremenchugsky PhD ME

INTRODUCTION: We evaluated the ability of a servo oxygen-control system (SS) to maintain oxygen concentration, or [O_2], and carbon dioxide concentration, or [CO_2], in an incubator within a narrow range while the percentage of O_2 and CO_2 and flow of gas mixtures supplied to the incubator were varied. MATERIALS & METHODS: To simulate high inspiratory flow and O_2 demands, we suctioned gas from the incubator through a catheter continuously at 5 L/min. During suctioning, a respiratory mass spectrometer (MS) was used to sample [O_2] at 48 equally spaced points at 3 heights within the incubator with the SS O_2 control set, in turn, at 24, 35, 55, and 75%. To test CO_2% at these oxygen concentrations, a dry mixture of 4.84% CO_2 and 95.16% O_2 was insufflated into the incubator at 1.0 L/min with the suction pump off while CO_2% was sampled by MS at each sampling point. Suction, insufflation, and SS flows were measured by a pneumotachometer. RESULTS: With the incubator portholes closed, the O_2% in the incubator did not differ from SS set values more than 1.1% (ie, difference in actual readings) at any sampling point. Similar results were obtained during the patient-care simulation when the rear port iris diaphragms were used. Drops in [O_2] and restoration times for [O_2] were unacceptable when front ports (without diaphragms) were used. No increase in CO_2% above atmospheric baseline (0.03%) was observed during the insufflation of 4.84% CO_2 into the incubator. CONCLUSIONS: Because our simulations were designed to mimic extreme clinical conditions, we believe that SS adequately controlled gas concentrations. [Respir Care 1996;41(8):724-727]

Introduction

Although incubators can provide safe, humid, and neutral thermal environments for neonates, previous studies have established that incubators do not reliably maintain specific oxygen concentrations [O_2].[1-4] For this reason, an oxygen hood is often used within an incubator to maintain a stable [O_2]. However, when an oxygen hood within the confines of an incubator is used with a nebulizer, increased sound levels pose a risk for hearing loss.[5,6] Supplying oxygen to hoods or incubators can also result in an oxygen-layering effect, with the highest [O_2] found at the bottom of the apparatus.[1,2] Increased carbon dioxide concentrations [CO_2] have also been reported when gas flow to the hood or incubator is inadequate.[7] We tested a servo oxygen-control system* (ServO$_2$, SS) developed to alleviate the problem of unstable [O_2] when supplemental O_2 is supplied to incubators. We also sought to determine whether the [CO_2] within the incubator remains at atmospheric level while the SS is in use.

Mr Dennison is Assistant Professor, Medical College of Georgia, School of Allied Health Sciences, and Dr Brudno is Associate Professor, Medical College of Georgia—Augusta, Georgia. Dr Lain is Clinical Manager, Healthdyne Technologies, Marietta, Georgia; and Dr Kremenchugsky is Principal Mechanical Engineer, Ohmeda Inc, Columbia, Maryland.

An abstract of this paper was presented at the OPEN FORUM during the 41st Annual Convention and Exhibition of the American Association for Respiratory Care, in Orlando, Florida, December 3-6, 1995.

This study was supported by Ohmeda Inc, Madison, Wisconsin.

Correspondence: Frank Dennison MEd RRT RPFT, Respiratory Therapy Department, MCG HM-143, Augusta GA 30912.

*Suppliers of commercial products are listed in the Product Sources section at the end of the text.

Materials & Methods

To evaluate the SS, we constructed a metal grid that provided a framework for sampling the gas mixture within the incubator at 48 equally spaced points at each of 3 heights across an area 40 × 60 cm (48 total sampling points, Fig. 1). The heights were chosen to simulate the position of a patient's airway adjacent to the mattress as in the prone position (0 level), at a medium height for a patient in the supine position (10-cm level), and at the top of the incubator (25-cm level) to test for any layering effect on O_2 within the incubator. To test maintenance of $[O_2]$ during simulated high inspiratory flow and oxygen demand, we used a suction pump to apply continuous suction at 5 L/min through a catheter placed at the head of the mattress within the incubator. The first test was conducted with all portholes closed and continuous suction applied. A respiratory mass spectrometer MS, which reports concentration as O_2% with a reported accuracy of ±1%, volume/volume (v/v), was used to sample gas within the incubator through a gas capillary tube 3 m in length. The sampling tip of the capillary was attached to the end of a metal rod that allowed the tip to be inserted through a small opening in the rear porthole's iris diaphragm and to be moved along the metal grid to each of the 48 sampling points. This permitted us to test the environment with all portholes effectively closed. The sampling tip was placed for 3 to 5 seconds at each of the 48 sampling points with the SS O_2% control set, in turn, at 24, 35, 55, and 75%. This testing procedure was repeated 3 times at each O_2% setting (48 × 3 × 4 = 576 samples.). An oxygen analyzer (accuracy ± 2% v/v) was also used to record incubator O_2% at mattress level throughout the study. We conducted another test for $[O_2]$ maintenance using the same procedure, sampling O_2% once while personnel placed their arms through 2 front portholes of the incubator and again while they placed their arms through the iris diaphragms of the 2 rear portholes (48 × 2 × 4 = 348 samples). These procedures were conducted to determine the SS's capacity to maintain the set O_2% levels during simulated conditions of infant nursing care.

To test for CO_2 clearance, a dry mixture of 4.84% CO_2 and 95.16% O_2 was insufflated into the incubator at 1.0 L/min to simulate expired CO_2. The CO_2% was measured by MS at the 48 sampling points during the insufflation procedure while O_2% was maintained, in turn, at 24, 35, 55, and 75%. Gas was not suctioned from the incubator during the test for CO_2 clearance so that CO_2 could only be cleared from the environment by the flow of gas supplied to the incubator from the SS. As an additional test to determine the SS's capacity to clear CO_2 from the incubator's environment, a mixture of 4.84% CO_2 and 95.16% O_2 was insufflated into the incubator with the SS temporarily turned off so that P_{ECO_2} levels (tension of CO_2 in expired gas) in the incubator could rise and stabilize. Then with the SS turned back on and set at 21%, CO_2 clearance was measured by the MS at 5-minute intervals for 40 minutes at 0 level. The CO_2% was then measured at each of the 48 sampling sites.

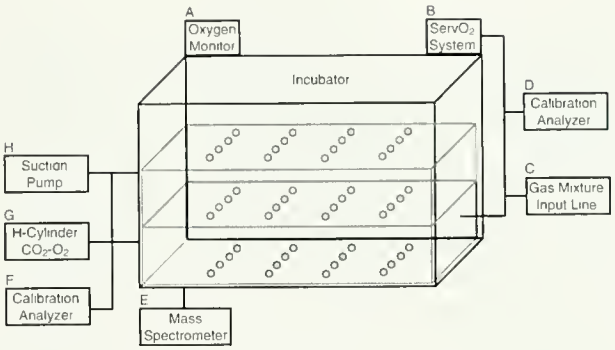


Figure 1. Schema of experimental setup used to evaluate simulations of clinical care of an infant in an Ohio Care Plus Incubator supplied by a $ServO_2$ Oxygen Control System. (A) Oxygen monitor placed on incubator measured oxygen concentration via a sensor placed at head of mattress. (B) $ServO_2$ system unit on incubator that supplied various O_2% and flows through tubing to input at C to maintain the set O_2% within the incubator. (D) Pneumotachograph (so-called calibration analyzer) connected in line by tubing from the $ServO_2$ to the incubator. (E) Respiratory mass spectrometer measured O_2% and CO_2% within the incubator via capillary tubing. A metal grid constructed in the incubator was used as a guide to move the capillary tubing to 48 equally spaced sampling sites at 3 heights. (F) Calibration analyzer connected into supply lines measured flow of 4.84% CO_2 (balance O_2) when it was being insufflated into the incubator from the H-cylinder at G, and also the flow of gas when it was being suctioned from the incubator by a suction pump at H.

During the O_2%-maintenance and CO_2-clearance testing procedures, suction, insufflation and SS flows were measured by a pneumotachometer (so-called calibration analyzer) with a reported accuracy of ±1%. All equipment had recent certified calibrations performed according to the manufacturer's guidelines. We calculated mean values and standard deviations for the O_2%s measured via MS compared to the set O_2% at the 3 heights (Table 1). We anticipated that for this evaluation descriptive statistics would allow determination of the clinical importance of any differences observed.

Table 1. Measured Values of O_2% at Various Levels of Set O_2% at Three Heights within a Closed Incubator

Height (above mattress)	Set O_2% = 24	Set O_2% = 35	Set O_2% = 55	Set O_2% = 75
0 cm	23.2 (0.1)*	34.3 (0.1)	53.9 (0.0)	74.0 (0.1)
10 cm	23.2 (0.0)	34.5 (0.0)	53.9 (0.1)	74.0 (0.1)
25 cm	23.2 (0.0)	34.3 (0.0)	54.0 (0.0)	74.0 (0.1)

* Values are mean (SD); n = 48 for each O_2% at each height.

Results

Mean (SD) values of the O_2% measured in the incubator at each of 3 heights (n = 48) compared to set O_2% are presented

in Table 1. Differences in MS-measured O_2% compared to the set O_2% levels were never greater than 1.1% (eg, 53.9 O_2% versus the set 55 O_2%) for any of the measurements during operation of the incubator with doors and portholes closed. The oxygen monitor recorded incubator O_2% in agreement with the SS set O_2% throughout the study with the portholes closed.

For a set O_2% of 24 and measured O_2% of 23.2 with personnel placing arms through front portholes, the measured O_2% dropped to 22.5% within 60 seconds and returned to the measured baseline (23.2 O_2%) at all levels within 5 minutes. At a set O_2% of 35 and measured O_2% of 34.5, the O_2% dropped to 30% within 60 seconds, then rose, and fluctuated from 33-34% at all 48 sampling points, within 8 minutes. The measurements were terminated after 10 minutes with conditions unchanged. With a set O_2% of 55 and measured O_2% of 53.9, the O_2% dropped within 60 seconds and fluctuated at each sampling point from 39-46% without further elevation for 10 minutes, at which point we stopped measurements. At the set O_2% of 75, results were similar with fluctuations in O_2% from 41-49%. When personnel placed their arms through the iris diaphragms of the rear portholes to simulate provision of patient care, there was no change in the measured O_2% at any sampling point compared to measurements with the portholes closed. The elastic bands in the plastic iris diaphragms maintained a tight seal around the arms of personnel extending their arms into the incubator, and the set O_2% at the levels tested were maintained.

During the test for CO_2 clearance, there was no increase in CO_2% above atmospheric baseline (0.03%) at any sampling point during insufflation of 1.0 L/min of 4.84% CO_2 into the incubator. Results are presented graphically in Figure 2 for the test of CO_2 clearance after the CO_2% of the gas mixture in the incubator had stabilized at approximately 4.0%. The highest CO_2% recorded at any sampling point was 4.12%. At the 0 level the MS capillary, placed in the center of the mattress, recorded 4.07% CO_2 at the start of the test and descended in a curvilinear fashion to 0.10% or less within 40 minutes (Fig. 2). CO_2% was ≤ 0.10% at the 48 sampling points at the end of the 40-minute period.

Suction flow was measured at 5 L/min and insufflation flow at 1 L/min by the pneumotachograph and were maintained throughout the testing except during the CO_2 clearance test. The measured SS flows that maintained the set O_2% within the incubator fluctuated from 12.3 to 15.7 L/min during testing, with the portholes closed and from 12.3 to 19.5 L/min during testing, with 2 portholes open.

Discussion

Our data demonstrate that the SS is an effective system in maintaining set O_2% and clearing CO_2 from an incubator during simulations of clinical use. However, it is important to point out that our results cannot be extrapolated to apply to other incubator models.

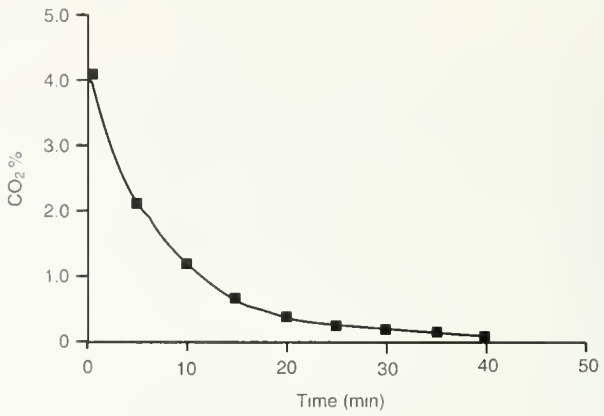


Fig. 2. Rate of CO_2 clearance from the incubator, following stabilization at approximately 4.0% CO_2. CO_2% was lowered to 0.1% or less by ServO_2 system within 40 minutes (a decrease in concentration of 1% in 9 minutes).

It has been the experience of other investigators that O_2% and CO_2% in incubators and hoods may be unstable.[7] Flows of blended gas delivered at 12-15 L/min to hoods have been recommended for stable [O_2] and flows greater than 7 L/min to ensure clearance of CO_2.[7] These problems are apparently eliminated with the SS, according to our data. The SS automatically varies the [O_2] and flow to maintain a set O_2% and to clear CO_2. Although we did not measure variations in delivered O_2% during operation of the SS, we did measure the delivered flow from the SS to the incubator. The SS delivered blended gas to the incubator within the range of approximately 12-20 L/min throughout the testing procedures, and regardless of how the delivered O_2% level varied, the SS maintained the O_2% and cleared the CO_2. Thus, the SS may often obviate the need for oxygen hoods, humidifiers, and nebulizers in incubators, resulting in a possible reduction in costs for respiratory care. To our knowledge, no precedent has been established in the research literature for quantitating clearance of CO_2 from incubators. This procedure does, however, provide a method for empirical evaluation of CO_2 clearance so that comparisons among incubators can be made in future research (Fig. 1).

Although there are small openings in the Ohio Care Plus Incubator for inserting monitoring lines and various types of tubing, the [O_2] remained stable throughout the incubator under high O_2 demands. Normal O_2 consumption and CO_2 production for a large infant can be estimated to be 33 mL/min[7,8] (assume a 12-pound infant with respiratory exchange ratio of 1.0, for calculations). Normal inspiratory flow demand for an infant is approximately 2-3 L/min for 0.5 s/breath. To evaluate the SS to ensure that these demands could be met, our simulation evacuated (consumed) O_2 at a rate of 1.2 to 3.75 L/min from the incubator's environment because inspiratory flow demand (suction) was con-

tinuous at 5 L/min at the set O_2% levels tested. For example, at a set O_2% of 24 with 5 L/min suction, 1.2 L/min O_2 (0.24×5 L/min = 1.2 L/min) is evacuated from the incubator's environment.

We considered statistical analysis of any comparisons among sampled data to be unnecessary in this study. The accuracy of the data sampling equipment was ± 1% and there was little variability in the measurements (Table 1) from one sampling site to another at the different O_2% (except at the high O_2% with portholes open). For example, during the sampling at the 48 sample sites with portholes closed, the O_2% indicated by the MS would sometimes fluctuate ± 0.1% during a sampling interval of 3-5 seconds for the SS set O_2% being tested. We believe that such fluctuations in O_2% are clinically meaningless. Because of the sample size and consistency of measured values, the differences at a given level could not be statistically significant.

The 4.84% CO_2 insufflated into the incubator corresponded to an environmental P_{ECO_2} of approximately 28.5 torr at sea level [(760 torr − 47 torr H_2O) (0.04 F_{CO_2}) = 28.5 torr], which is a normal peak P_{ECO_2}/breath for a patient.[8] The 4.84% CO_2 was insufflated into the incubator at 1.0 L/min, which is 48.4 mL/min expired CO_2, or more than 2 times the volume of CO_2 that would be expired by an 8-pound infant.[7] Thus, the simulated demands placed on the SS for O_2% maintenance and CO_2 clearance were probably worst-case scenarios and could be considered at least representative of clinical conditions.

During simulated patient care through the front portholes, MS-measured O_2% levels were reduced. For example, the MS-measured baseline environmental O_2% level of 23.2% dropped to 22.5% (a drop equal to 3% of the initial value) during patient care simulation—a drop that lasted < 1 minute before returning to the baseline value during the next 5 minutes. At the set O_2% of 35, O_2% dropped from the MS-measured baseline of 34.3% to 30% (a drop equal to 13% of the initial value), and then returned to approximately 3% to 4% of baseline values at the 48 sampling points over 8 minutes. However, if an infant was sensitive to fluctuations in [O_2] at these levels, the problem could easily be avoided by performing patient care procedures through the iris diaphragms provided for the rear portholes. This safeguard should always be practiced at the higher [O_2] of 55-75.

Although there is no standard with which to compare the CO_2% clearance time that we recorded, the SS's capacity to clear CO_2 from 4.07% to 0.10% or less in 40 minutes does serve to demonstrate that high levels of CO_2 can be flushed from an incubator by the SS.

Conclusion

According to our data, SS maintains O_2% and eliminates CO_2 in incubators. With portholes closed, deviation from set O_2% is < 1 percentage point, and expired [CO_2] did not rise above baseline under simulated worse-case scenarios. The use of SS may eliminate the need for oxygen hoods and nebulizers in this model of incubator, thereby decreasing the risk of hearing loss and reducing medical costs.

PRODUCT SOURCES

Oxygen Analyzer:
Ohmeda 5120 Oxygen Monitor, Ohmeda Inc, Madison WI

Mass Spectrometer:
Perkin-Elmer MGA 1100, Perkin-Elmer, Paloma CA

Servo Oxygen System:
ServO_2 Oxygen Control System, Ohmeda Inc, Madison WI

Calibration Analyzer:
Timeter RT-200 Calibration Analyzer, Allied Health Products, St Louis MO

Suction Pump:
Egnell Suction Pump, Ameda/Egnell Corporation, Cary IL

Incubator:
Ohio Care Plus Incubator, Ohmeda Inc, Madison WI

REFERENCES

1. McPherson SP. Gas administration devices. In: Respiratory therapy equipment, 2nd ed. St Louis: CV Mosby, 1981:33.
2. Ward JJ. Equipment for mixed gas and oxygen therapy. In: Barnes TA. Core textbook of respiratory care practice. 2nd ed. St Louis: Mosby-Year Book Inc, 1994:424-426.
3. Medoff-Cooper B. Transition of the preterm infant to an open crib. J Obstet Gynecol Neonatal Nurs 1994;23(4):329-335.
4. Bell EF, Rios GR. A double-walled incubator alters the partition of body heat loss of premature infants. Pediatr Res 1983;17(2):135-140.
5. Beckham RW, Mishoe SC. Sound levels inside incubators and oxygen hoods used with nebulizers and humidifiers. Respir Care 1982; 27(1):33-40.
6. Mishoe SC, Brooks WC, Dennison FH, Hill KV, Frye T. Octave wave-band analysis to determine sound frequencies and intensities produced by nebulizers and humidifiers used with hoods. Respir Care 1995; 40(11):1120-1124.
7. Gale R, Redner-Carmi R, Gale J. Accumulation of carbon dioxide in oxygen hoods, infant cots, and incubators. Pediatrics 1977;60(4): 453-456.
8. Martin LD, et al. Principles of respiratory support and mechanical ventilation. In: Rogers MC, editor. Textbook of pediatric intensive care. Baltimore: Williams and Wilkins, 1992:146-153.

The Effect of Airway Leak on Tidal Volume during Pressure- or Flow-Controlled Ventilation of the Neonate: A Model Study

Robert L Chatburn RRT, Teresa A Volsko RRT, and Mohamad El-Khatib PhD

Leaks associated with uncuffed endotracheal tubes (ETTs) complicate mechanical ventilation of the neonate. The variable nature of leaks and the possibility of different modes of ventilation suggest an optimal strategy for stability of tidal volume (V_T). This study evaluated the effect of leak on V_T during pressure-controlled ventilation (PCV) or flow-controlled ventilation (FCV). METHOD: We used a lung model consisting of an elastic bellows (compliance = 1 mL/cm H_2O) attached to a 3.0-mm ETT with a 3-way stopcock. One port of the stopcock was attached to a fixed-orifice leak (% leak = 19-34% depending on ventilator settings). A ventilator generated either constant inspiratory pressure (as in PCV) or constant inspiratory flow (as in FCV) at the same V_T. Inspired and expired volumes were measured with a neonatal monitor. Calibration was verified with a syringe. The effect of leak on exhaled tidal volume (V_E) was defined as:

$$\%\Delta V_E = \frac{V_E \text{ (leak off)} - V_E \text{ (leak on)}}{V_E \text{ (leak off)}} \times 100$$

Large (≈15 mL) and small (≈7 mL) V_Ts were used with long (0.8 s) and short (0.3 s) inspiratory times (T_Is). Each combination was evaluated 3 times (n = 3). Differences in $\%\Delta V_E$ were evaluated with unpaired *t* tests. A theoretical model was derived to generalize results. RESULTS: PCV resulted in a significantly smaller leak effect for all conditions except small V_T and short T_I. The largest difference was seen with small V_Ts and long T_Is (leak effect for FCV = 44% vs PCV = 18%). The theoretical model predicts that for FCV, $\%\Delta V_E$ increases as T_I increases. For PCV, $\%\Delta V_E$ at first increases as T_I increases and then decreases to a constant value. For both FCV and PCV, gas exchange will probably be most stable with short T_Is in the presence of a leak. CONCLUSION: An optimum strategy for dealing with intermittent airway leaks might be short T_Is and relatively large V_Ts independent of mode. At small V_Ts and long T_Is, ventilation should be more stable with PCV. [Respir Care 1996;41(8):728-735]

Mr Chatburn is Director, Respiratory Care Department, Rainbow Babies & Childrens Hospital, and Instructor, Department of Pediatrics, Case Western Reserve University, Cleveland, Ohio; Ms Volsko is Supervisor, Respiratory Care Department, St Elizabeth's Hospital, Youngstown, Ohio; and Dr El-Khatib is associated with the Department of Pharmacology & Critical Care Medicine, Rainbow Babies & Childrens Hospital at University Hospitals of Cleveland, Cleveland, Ohio.

An abstract based on this study was presented at the RESPIRATORY CARE OPEN FORUM during the Annual Meeting of the American Association for Respiratory Care, in Orlando, Florida, December 2-5, 1995.

Reprints & Correspondence: Robert L Chatburn RRT, Director, Respiratory Care Department, Rainbow Babies & Childrens Hospital, 11100 Euclid Ave, Cleveland OH 44106.

Introduction

Uncuffed endotracheal tubes (ETTs) complicate assisted ventilation due to variable leaks around the artificial airway. Leak problems are common in infants and children who are ventilated with small tidal volumes (V_Ts). This fact has led some manufacturers to design "leak compensation" devices in their ventilators (eg, Bird VIP). Because leaks are often intermittent (eg, due to changes in head or body position), they can cause alterations in delivered minute ventilation leading to instability of gas exchange. This becomes a problem particularly when the leak cannot be minimized through repositioning or reintubation with a larger ETT.

Recent technologic advances have made it possible to ventilate small children with either volume/flow-controlled or pressure-controlled modes. In a chapter about pressure-controlled ventilation (PCV), some well respected authors point out a disadvantage of the volume-controlled mode by saying that "Volume-cycled ventilators may ... be considered unsatisfactory because an unknown amount of the preset volume will leak from the airway when uncuffed endotracheal tubes are used."[1] There is no mention of how leaks affect V_T during PCV. This could imply that PCV is somehow better when a leak is present. Unfortunately, unsupported statements of opinion and their implied meanings are often echoed by other authors, and thus is born a new dogma unsupported by fact. For example, Whitaker says that during volume-controlled ventilation, "An unknown amount of tidal volume is lost around the tube during inspiration." with no references.[2] In a later section on the disadvantages of PCV, Whitaker does not mention the effect of leak, which could again lead the reader to conclude that it is not a factor in V_T delivery. However, both theory and data suggest that V_T decreases with a leak in both modes,[3] although, to our knowledge, no study has directly compared these two modes under conditions of intermittent leak.

The purpose of our study was to compare the effect of a fixed leak on V_T delivery during PCV and flow-controlled ventilation (FCV). We postulated that an optimal ventilator management strategy can be developed to deal with leaks and maintain the stability of volume delivery with uncuffed ETTs. Our null hypothesis was that the effect of a fixed leak on V_T, defined as the percent change in exhaled volume between leak and no-leak conditions, would be the same for PCV as FCV.

Methods

We used a lung model consisting of an elastic bellows (compliance = 1 mL/cm H_2O) attached to a 3.0-mm ID ETT with a 3-way stopcock. One port of the stopcock was attached to a fixed-orifice leak. We chose a lung model rather than a patient so we could control the main experimental variable: presence and size of leak. The size of the leak was measured with a BICORE CP 100 Neonatal Monitor* while the model was ventilated. Leak size was defined as the difference between the measured inspired and expired V_T expressed as a percentage of inspired V_T. The percent leak measured and recorded for each experimental condition varied from 19 to 34%, depending on mode and ventilator settings (ie, for a fixed-orifice size, the smaller the V_T and the longer the inspiratory time (T_I), the larger the leak). This range of leak is often seen in ventilated neonates with ETTs sized 2.5-3.5 mm-ID.[4]

The placement of the flow sensor in this model reflects the effect of gas flow through the leak during the entire ventilatory cycle. With one sensor, it is not possible to separate the true exhaled volume from the volume lost through the leak. The exhaled volume will be underestimated because of flow through the leak during the expiratory phase. However, we chose this methodology for 4 reasons: (1) it is easier to conduct and reproduce with a typical bedside pulmonary function monitor rather than laboratory flow sensors, amplifiers, and recorders; (2) we avoid errors introduced by differences in sensor bias or by changing the position of a single sensor (ie, between the patient Y and the ET tube versus between the leak and the test lung) due to flow turbulence caused by large diameter adapters placed in a small diameter airway; (3) the characterization of the leak size (ie, % leak) and other measurements are clinically relevant as clinicians are limited to only one sensor placed between the patient Y and the ETT; and (4) the error introduced in the measurement of V_E should be constant between PCV and FCV because expiration was passive from the same V_Ts and expiratory times, such that any differences in V_E should be due only to the experimental variables.

The model was ventilated with a Newport Wave ventilator. This ventilator can deliver breaths in either the pressure- or flow-controlled modes. A dual heated-wire infant circuit connected the lung model to the ventilator. The water level of the humidifier was kept at "max fill level" to eliminate variations in V_T delivery due to compressible volume loss. The heater was turned off.

Data were recorded 3 times for each of 16 experimental conditions (ie, all combinations of: large and small V_Ts, short and long T_Is, pressure control or flow control, leak on or leak off). Both pressure- and flow-controlled modes were set to deliver inspired volumes of 7 and 15 mL while the leak was turned off. These volumes represent a typical V_T range for infants of about 1,500 grams. Positive end-expiratory pressure (PEEP) was set at 0 to prevent drift in the volume signal as gas escaped through the leak. Inspiratory flow was manipulated in an attempt to produce a rectangular pressure waveform during PCV and a rectangular flow waveform with FCV. This was done to more readily distinguish any differences between these two control modes. However, rectangular waveforms were not completely developed with small V_T and short T_I settings (Fig. 1). Once baseline measurements had been made, the leak was turned on and measurements repeated.

Inspired and expired volume, T_I, % tube leak, and pressure/volume/flow waveforms were recorded for each experimental condition. Mean airway pressure ($\bar{P}_{aw}$), measured at the ventilator was verified with the measurements obtained with the monitor. Prior to data collection, the monitor was calibrated with an infant flow transducer according to manufacturer's specifications. This calibration was then verified manually, with the breath average set at 10 breaths. We used a 100-mL calibration syringe with the plunger stop set at the 20-mL mark. After calibration, bias (mean difference between measured and syringe volume) was 0.1 mL for inspiration and 0.4 mL for expiration.

*Suppliers of commercial products are listed in the Product Sources section at the end of the text.

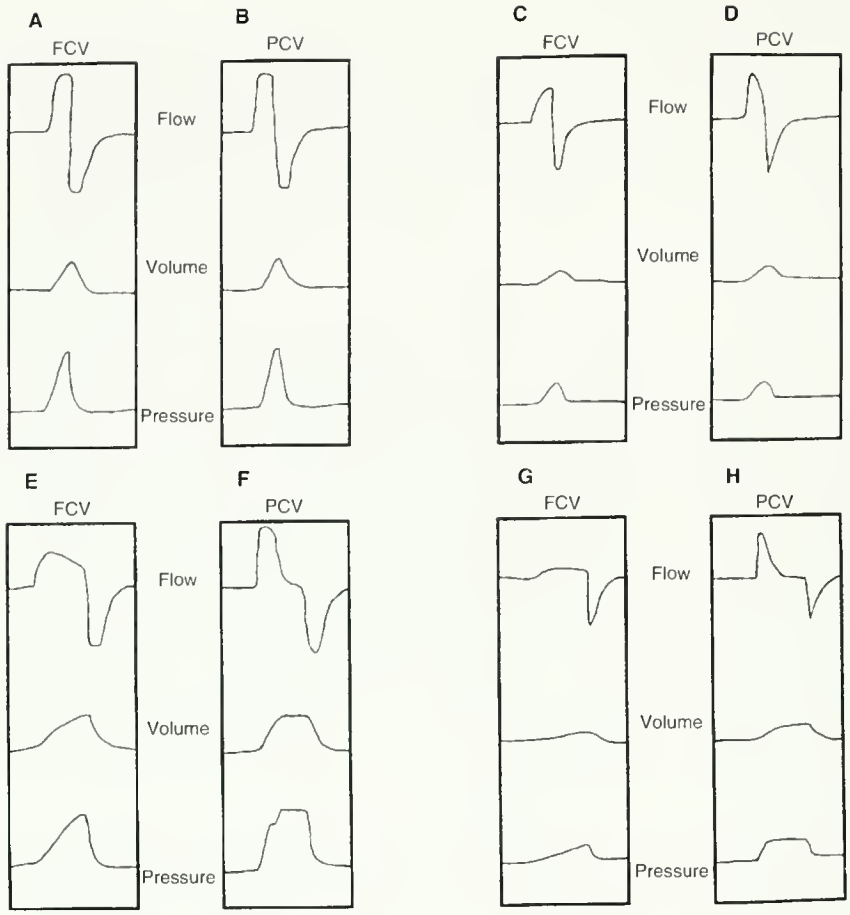


Fig. 1. Representative waveforms for baseline (leak off) experimental conditions: A. flow-controlled ventilation (FCV), large tidal volume (V_T) = 15 mL, short inspiratory time (T_I) = 0.3 s; B. pressure-controlled ventilation (PCV), large V_T = 15 mL, short T_I = 0.3 s; C. FCV, small V_T = 7 mL, short T_I = 0.3 s; D. PCV, small V_T = 7 mL, short T_I = 0.3 s; E. FCV, large V_T = 15 mL, long T_I = 0.8 s; F. PCV, large V_T = 15 mL, long T_I = 0.8 s; G. FCV, small V_T = 7 mL, long T_I = 0.8 s; H. PCV, small V_T = 7 mL, long T_I = 0.8 s.

The flow transducer was placed between the patient Y and the ETT and volume was derived by integration of the flow signal.

The key outcome variable was the volume of gas lost through the leak expressed as a percentage change in expired V_T:

$$\%\Delta V_E = \frac{V_E \text{ (leak off)} - V_E \text{ (leak on)}}{V_E \text{ (leak off)}} \times 100$$

Defined in this way, a larger number for $\%\Delta V_E$ represents a larger effect of the leak and a more adverse effect on gas exchange.

Unpaired *t* tests were used to evaluate the leak effect for PCV and FCV at each V_T and T_I setting. Statistical significance was set at $p = 0.05$.

Because the physical lung model was unable to generate data on inspired V_T, we supplemented our study with data from a mathematical model of an equivalent electrical model (Fig. 2). FCV was represented as constant current and PCV as constant voltage inputs. Equations were derived for lung volume as a function of time using the Laplace Transform (Appendix).

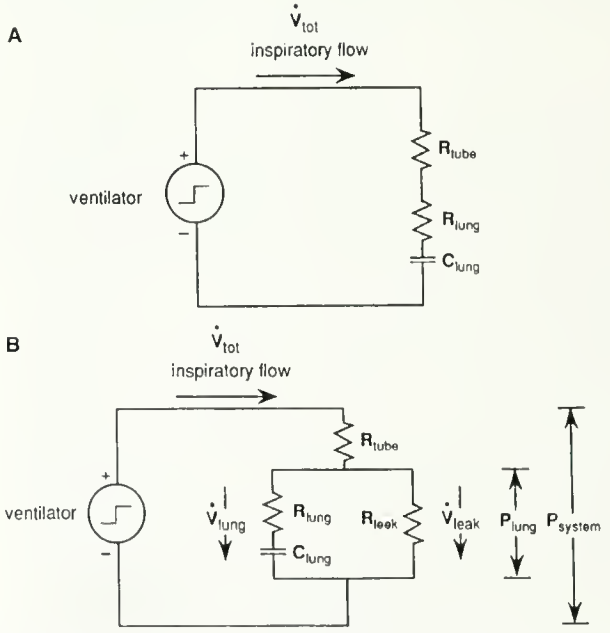


Fig. 2. Electrical analog of physical model used to generate a corresponding mathematical model with leak off (A) and with leak on (B). R = resistance, C = compliance, P = pressure, $\dot{V}$ = flow. Parameter values for numerical analysis were: R_{aw} = 70 cm H_2O s^{-1}, R_{lung} = 10 cm H_2O, C_{lung} = 1 mL/cm H_2O, R_{leak} = 70 cm H_2O/L/s.

Results

Raw data for both FCV and PCV are shown in Figure 3. Waveforms corresponding to the experimental conditions are

V_T = 15 mL, T_I = 0.3 s

	FCV off	FCV on	PCV off	PCV on
V_I	15.3	14.9	15.5	16.0
	15.4	14.9	15.8	16.0
	15.3	15.0	15.6	16.1
mean	**15.3**	**14.9**	**15.6**	**16.0**
SD	0.1	0.1	0.2	0.1
V_E	14.9	13.0	15.3	14.0
	15.2	12.7	15.5	13.9
	15.3	12.7	15.4	14.0
mean	**15.1**	**12.8**	**15.4**	**14.0**
SD	0.2	0.2	0.1	0.1
$\bar{P}_{aw}$	2.0	2.0	2.0	2.0
	2.0	2.0	2.0	2.0
	2.0	2.0	2.0	2.0
mean	**2.0**	**2.0**	**2.0**	**2.0**
SD	0.0	0.0	0.0	0.0
%Leak	0.0	7.0	0.0	12.0
	0.0	8.0	0.0	12.0
	0.0	8.0	0.0	12.0
mean	**0.0**	**7.7**	**0.0**	**12.0**
SD	0.0	0.6	0.0	0.0

V_T = 7 mL, T_I = 0.3 s

	FCV off	FCV on	PCV off	PCV on
V_I	7.5	7.0	7.2	7.2
	7.0	7.6	7.2	7.3
	7.4	7.5	7.1	7.7
mean	**7.3**	**7.4**	**7.2**	**7.4**
SD	0.3	0.3	0.1	0.3
V_E	7.5	5.2	7.1	6.0
	7.0	5.6	7.1	5.8
	7.4	6.1	7.0	6.3
mean	**7.3**	**5.6**	**7.1**	**6.0**
SD	0.3	0.5	0.1	0.3
$\bar{P}_{aw}$	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0
mean	**1.0**	**1.0**	**1.0**	**1.0**
SD	0.0	0.0	0.0	0.0
%Leak	0.0	16.0	0.0	17.0
	0.0	14.0	0.0	17.0
	0.0	14.0	0.0	16.0
mean	**0.0**	**14.7**	**0.0**	**16.7**
SD	0.0	1.2	0.0	0.6

V_T = 15 mL, T_I = 0.8 s

	FCV off	FCV on	PCV off	PCV on
V_I	15.0	15.8	15.2	15.4
	15.2	15.4	15.1	15.3
	15.1	15.4	15.1	15.4
mean	**15.1**	**15.5**	**15.1**	**15.4**
SD	0.1	0.2	0.1	0.1
V_E	14.9	10.8	15.1	13.6
	15.0	10.0	15.0	13.1
	15.0	10.1	15.0	13.0
mean	**15.0**	**10.3**	**15.0**	**13.2**
SD	0.1	0.4	0.1	0.3
$\bar{P}_{aw}$	5.0	5.0	6.0	6.0
	5.0	5.0	6.0	6.0
	5.0	5.0	6.0	6.0
mean	**5.0**	**5.0**	**6.0**	**6.0**
SD	0.0	0.0	0.0	0.0
%Leak	0.0	20.0	0.0	23.0
	0.0	20.0	0.0	23.0
	0.0	20.0	0.0	23.0
mean	**0.0**	**20.0**	**0.0**	**23.0**
SD	0.0	0.0	0.0	0.0

V_T = 7 mL, T_I = 0.8 s

	FCV off	FCV on	PCV off	PCV on
V_I	7.4	7.4	7.2	6.9
	7.6	7.6	7.0	7.0
	7.5	7.7	7.1	6.8
mean	**7.5**	**7.6**	**7.1**	**6.9**
SD	0.1	0.2	0.1	0.1
V_E	7.2	4.0	7.1	5.8
	7.6	4.0	6.9	5.8
	7.4	4.5	7.1	5.8
mean	**7.4**	**4.2**	**7.0**	**5.8**
SD	0.2	0.3	0.1	0.0
$\bar{P}_{aw}$	1.0	1.0	2.0	2.0
	1.0	1.0	2.0	2.0
	1.0	1.0	2.0	2.0
mean	**1.0**	**1.0**	**2.0**	**2.0**
SD	0.0	0.0	0.0	0.0
%Leak	0.0	20.0	0.0	16.0
	0.0	20.0	0.0	16.0
	0.0	20.0	0.0	15.0
mean	**0.0**	**20.0**	**0.0**	**15.7**
SD	0.0	0.0	0.0	0.6

Fig. 3. Experimental data to determine effects of different inspiratory times on tidal volume during pressure-controlled (PCV) and flow-controlled ventilation (FCV). V_I = inspiratory volume, V_E = exhaled tidal volume, $\bar{P}_{aw}$ = mean airway pressure.

shown in Figure 1. Calculated values for leak effect are graphed in Figure 4. In general, the effect of leak was less with PCV than with FCV. This result was most pronounced with a long T_I and a small V_T and least pronounced for short T_I and small V_T.

Ideal volume curves from the mathematical model are

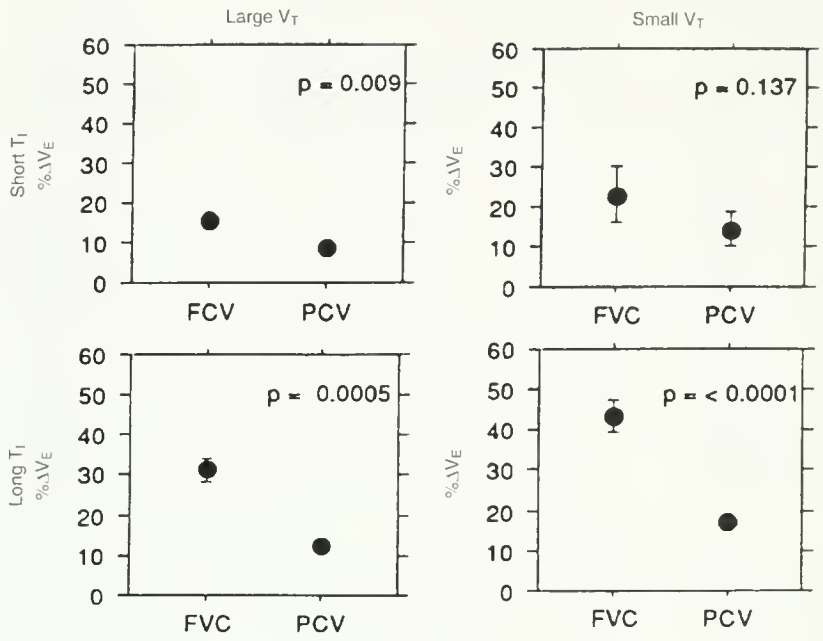


Fig. 4. The change in exhaled tidal volume created by the leak (ie, $\%\Delta V_E$) for each experimental combination of mode, tidal volume (V_T), and inspiratory time (T_I). FCV = flow-controlled ventilation, PCV = pressure-controlled ventilation. Results are mean (SD).

shown in Figure 5. With leak on, PCV results in a more rapid rise in volume as a function of time than FCV. Thus, for any set T_I, PCV results in a larger V_T when the leak is present.

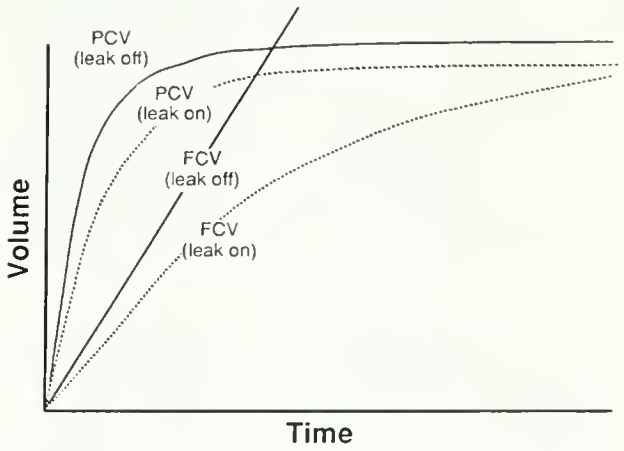


Fig 5. Volume/time curves for both modes of ventilation, leak on and leak off derived from the mathematical model. Pressure-controlled ventilation (PCV) generally results in a faster rise in lung volume, resulting in a larger tidal volume for any given inspiratory time. The difference between PCV and flow-controlled ventilation (FCV) is probably not clinically important for inspiratory times less than 0.3 seconds.

Discussion

Leaks around the ETT are common in neonates with uncuffed tubes. One study[5] suggests that the normal leak (difference between inspired and expired volume as percent of inspired volume) is about 10% ± 9% whereas some infants with evidence of tube obstruction had leaks of 64% ± 15%. Another study of 13 intubated infants found leaks of 15% to 35%.[6] One source recommends that a tube leak > 20% indicates a compromised airway.[7] A more recent study by Bernstein et al[8] was able to describe the frequency distribution of leaks in 50 infants with appropriately sized ETTs (2.5-mm ID through 4-mm ID). They found that the mean (SD) leak size in infants was 15.6 (11)%. A minimal leak size of 1 to 10% was present in 30% of infants, leak size of 10% to 20% in 48% of infants, leak size of 20% to 30% in 14% of infants and leak size > 30% in 8% of infants. Of the infants studied, 70% had a leak size of > 10%. The investigators observed 3 cases in which inappropriately small ETTs resulted in leaks as large as 75%. They also note that despite the use of cuffed ETTs in adults, there is an incidence of 6% to 20% of "massive" airway leaks,[8] defined as >10% of the V_T.

Leaks can be insidious, changing greatly with small changes in patient position. Just moving the patient's head from one side to the other can cause a major leak and subsequent deterioration in gas exchange. Unless equipment for bedside pulmonary function evaluation is available, such leak effects can go unappreciated, and the infant's condition is simply judged to be "labile." If a large leak is identified, the infant may be reintubated with a larger tube. However, optimizing ventilator settings might minimize the leak effects and thus avoid the risks inherent in reintubation. This study suggests that increasing both the V_T and ventilatory rate might accomplish this goal in both FCV and PCV.

Our leak model also simulates lung leaks, such as bronchopleural fistula. Thus, ventilator settings may be optimized

in the same way when clinically important V_T is being lost through a chest tube. This hypothesis is supported by results of studies using high-frequency ventilation. The same basic theory applies: at low frequencies, inspiratory flow favors leak pathways because their impedance is almost entirely resistive (ie, not frequency dependent) compared to intact lung whose impedance is both resistive and capacitive (ie, frequency dependent with high impedance at low frequencies). At high frequencies, the impedance of intact-pathways decreases and relatively less flow follows leak pathways.[9]

The purpose of the mathematical model was to help visualize and generalize the reasons for the observed study effects. In Figure 5, the intersection of the 2 solid lines represents the target V_E being delivered at the set T_I for the no-leak condition. The shape of the 2 sets of curves show that PCV delivers more of the target V_E for any time less than the target T_I than does FCV. Because the lung-pressure curve has the same shape as the lung-volume curve (with a scale factor equal to volume/compliance) and because mean pressure is proportional to the area under the pressure-time curve,[10] PCV also delivers a larger mean lung pressure than FCV during inspiration. This suggests that an intermittent leak may have less effect on blood gas values during PCV than during FCV. However, the difference between modes in terms of leak effect (ie, the vertical distance between "leak off" and "leak on" curves in Figure 5 as a percentage of the leak off volume) for short T_I may become clinically unimportant as T_I decreases (eg, if frequency was increased at a fixed ratio of inspiratory-to-expiratory time, or I:E). More importantly, Figure 1 shows that for short T_Is (particularly with a large V_T) the ventilator was unable to generate a rectangular pressure waveform. Indeed, the PCV curves looked almost identical to the FCV curves, so it is not surprising that there was no difference in leak effect.

The theoretical waveforms in Figure 5 show that a leak causes lung volume to rise exponentially rather than linearly with FCV. The maximum lung volume is achieved (as time approaches infinity) when lung pressure (ie, lung volume/lung compliance) equilibrates with the pressure drop across the leak (ie, set inspiratory flow × leak resistance). In effect, FCV has been changed to PCV with the leak acting like a pressure-limiting valve. It is interesting to note that this observation substantiates Whitaker's statement that "The amount of leak will increase as lung compliance worsens..."[2] during FCV. In fact, leak will increase and V_T decrease as the impedance of the lung increases (ie, compliance decreases and/or resistance increases, see Equation 10 in Appendix).

The relative shapes of the 2 FCV curves indicate that V_E (leak off) increases while V_E (leak on) approaches a constant value. Thus $\%\Delta V_E$ increases as T_I increases. This would suggest that if FCV is to be used in the presence of an intermittent leak, gas exchange will be most stable with short T_I.

During PCV, lung volume always rises exponentially, but a leak limits the potential maximum lung volume (at infinite time) to a value equal to the pressure drop across the leak, rather than the set inspiratory pressure. Equation 6 in the Appendix shows that the maximum lung pressure is the set inspiratory pressure (above PEEP) times the factor $R_{leak}/(R_{leak} + R_{lung})$. As with FCV, the larger the leak, the smaller the pressure drop across it and the smaller the potential V_T. The relative shapes of the 2 PCV curves indicate both V_E (leak off) and V_E (leak on) approach a constant value, but at different rates. Thus $\%\Delta V_E$ at first increases as inspiratory time increases and then decreases to a constant value. Like FCV, if PCV is to be used in the presence of an intermittent leak, gas exchange will probably be most stable with short T_Is.

Both the experimental and theoretical results of this study represent the case of a normal lung. With diseased lungs (ie, low compliance and/or high resistance) the effect of air leaks might be more pronounced and detrimental. The current theoretical equations given in the Appendix and findings from a previous study[11] should allow the assessment of the effect of leaks in any disease state with either FCV or PCV.

A limitation of this study is that it models the behavior of fixed leaks only. Real leaks can be classified in at least four major types:

- Fixed-orifice leaks—this type of leak behaves as though gas is escaping through a hole with dimensions that do not change during either inhalation or exhalation.

- Variable-orifice leaks—by far the most common, this type of leak increases and then decreases in cross-sectional area as airway pressure increases and then decreases during mechanical ventilation. This makes physiologic sense because nonrigid portions of the trachea and upper airways are easily dilated by the application of positive pressure.

- Critical-opening-pressure, fixed-orifice leaks—with this type of leak, gas does not begin to escape until the airway pressure reaches some critical threshold; thereafter, the leak behaves as the fixed-orifice type.

- Critical-opening-pressure/variable-orifice leaks—as in the previous example, this type of leak does not present itself until the airway pressure reaches a critical threshold; thereafter, the leak aperture is variable in size.

Our study modeled a fixed-orifice leak, and we believe the qualitative conclusions might be applied to the other types of leaks:

1. Critical-opening-pressure, fixed-orifice leaks—A leak with a critical opening pressure would have the effect of delaying the presence of the leak effect. However, the delay would probably be longer for FCV because PCV results in a steeper tracheal pressure waveform such that the critical opening

pressure would be reached earlier in inspiration. Thus the leak might affect PCV relatively more than FCV for this model compared to our model. As a result, we could expect that the difference in $\%\Delta V_E$ between FCV and PCV might be smaller than that observed with the model we used. The $\%\Delta V_E$ may not reach significance in the case of small V_Ts, but there is no reason to believe that the qualitative effect, or the conclusion would be any different. That is, V_T tends to be more stable during PCV than during FCV, and the leak effect is minimized in either mode by using larger V_Ts and shorter T_Is.

2. Variable-orifice leaks—One can envision the simplest case: that the orifice varied between 2 resistances as airway pressure increased. This model would act like 2 fixed-orifice models in sequence such that the end result in terms of $\%\Delta V_E$ would be the result of volume delivered under the first condition plus the volume delivered under the second condition. Again, the qualitative effect, that PCV is more stable than FCV, would obtain, and the conclusions of our study would still be valid. Of course, in the real world the orifice would vary among an infinite number of resistances from small to large and back again. But this can be conceptualized as just a large number of fixed-orifice effects stacked together, much like an analog-to-digital converter would sample a continuously variable signal in a computerized pulmonary function analyzer.

3. Critical-opening-pressure, variable-orifice leaks—This class of leaks should behave as a combination of the above 2 types. Because neither a critical opening pressure nor a variable orifice would be expected to alter the general conclusions based on a fixed-orifice model, we see no theoretical reason why combining them would be any different.

Conclusion

This study indicates that instability of tidal volume caused by a fixed airway leak can be minimized by using pressure-controlled ventilation rather than flow-controlled ventilation. Increased tidal volume stability may lead to better gas exchange and lower the risk of pulmonary volutrauma. Either mode can be optimized in the presence of a leak by decreasing inspiratory time, and increasing the tidal volume.

PRODUCT SOURCES

Ventilator:
Newport Wave, Newport Medical Instruments, Newport Beach CA

Lung Model:
Neonatal Lung Model, IngMar Medical, Pittsburgh PA

Ventilator Circuit:
Isothermal Dual Heated Wire Circuit, Isothermal Systems Inc, Riverside CA

Monitor:
BICORE CP 100 Neonatal, Allied Health Care, St Louis MO

Calibrating Equipment:
100 cc Calibration Syringe 5510 Series, Hans Rudolph Inc, Kansas City MO

REFERENCES

1. Fox WD, Spitzer AR, Shutack JG. Positive pressure ventilation: pressure- and time-cycled ventilators. In: Assisted ventilation of the neonate, 2nd ed, Goldsmith J and Karotkin E, editors. Philadelphia: WB Saunders Co, 1988:146.
2. Whitaker K. Comprehensive perinatal and pediatric respiratory care. Albany: Delmar Publishers Inc, 1992:514-515.
3. Perez-Fontan JJ, Heldt GP, Gregory GA. The effect of a gas leak around the endotracheal tube on the mean tracheal pressure during mechanical ventilation. Am Rev Respir Dis 1985;132(2):339-342.
4. Schwab RJ, Schnader JS. Ventilator autocycling due to an endotracheal tube cuff leak. Chest 1991;100(4):1172-1173.
5. MacDonald K, Wirtshafter D, McEvoy C, Franceschini R. The use of a hot-wire anemometer in the differential diagnosis of neonatal endotracheal tube (ETT) obstruction (abstract) Respir Care 1988;33(10):886.
6. Fox WF, Schwartz JG, Shaffer TH. Effects of endotracheal tube leaks on functional residual capacity determination in intubated neonates. Pediatr Res 1979;13(1):60-64.
7. Cvetnic W, MacDonald K. Ventilator management of neonates and infants using respiratory mechanics. A casebook. Irvine CA: BICORE Monitoring systems, page 54 (no other publishing data given).
8. Bernstein G, Knodel E, Heldt GP. Airway leak size in neonates and autocycling of three flow-triggered ventilators. Crit Care Med 1995; 23(10):1739-1744.
9. Fernádes-Martorell P, Boynton B. High-frequency oscillatory ventilation and high-frequency flow interruption. In: New therapies for neonatal respiratory failure, Boynton BR, Carlo WA, Jobe AH, editors. New York: Cambridge University Press, 1995:235-237.
10. Primiano FP Jr, Chatburn RL, Lough MD. Mean airway pressure: theoretical considerations. Crit Care Med 1982;10(6):378-383.
11. Chatburn RL, El Khatib MF, Smith PG. Respiratory system behavior during mechanical inflation with constant inspiratory pressure and flow. Respir Care 1994;39(10):979-988.

Appendix

Because 2 parallel components experience the same pressure drop and 2 or more series components share the same flow, the following equations can be derived and solved using the Laplace Transform for constant inspiratory pressure (PCV) and flow (FCV) with and without an air leak.

General Terms

R = resistance
C = compliance
s = Laplace operator
t = time
$\dot{V}$ = flow
$\dot{V}_{tot}$ = total flow through system
V = volume
ΔP = constant inspiratory pressure
$\Delta\dot{V}$ = constant inspiratory flow

PCV without leak

$$\Delta P = Z_{system} \cdot \dot{V}_{tot}, \quad [1]$$

where Z_{system} = equivalent impedance of the lung and endotracheal (ETT) tube = $(R_{tube} + R_{lung}) + 1/sC$.

Solving [1] for $\dot{V}_{tot}$ and integrating over time,

$$V_{lung}(t) = V_{tot}(t) = \Delta P \cdot C_{lung} (1 - e^{-t/[C_{lung} R_{lung} + C_{lung} R_{tube}]}). \quad [2]$$

PCV with leak

$$\Delta P = R_{tube} \cdot \dot{V}_{tot} + Z_{lung} \cdot \dot{V}_{lung}, \quad [3]$$

$$\dot{V}_{Ttot} = \dot{V}_{lung} + \dot{V}_{leak}, \quad [4]$$

$$Z_{lung} \cdot \dot{V}_{lung} = R_{leak} \cdot \dot{V}_{leak}, \quad [5]$$

where Z_{lung} = impedance of the lung = $R_{lung} + 1/sC_{lung}$.

Solving [3], [4], and [5)]simultaneously for $\dot{V}_{lung}$ and integrating over time,

$$V_{lung}(t) = \frac{\Delta P \cdot C_{lung} \cdot R_{leak}}{R_{leak} + R_{tube}} \cdot (1 - e^{-t(R_{tube} + R_{leak})/[C_{lung} (R_{leak} R_{tube} + R_{leak} R_{lung} + R_{lung} R_{tube})]}). \quad [6]$$

FCV without leak

By directly integrating $\dot{V}_{tot}$ over time,

$$V_{lung}(t) = V_{tot}(t) = \Delta\dot{V} \cdot t. \quad [7]$$

FCV with leak

$$\dot{V}_{tot} = \dot{V}_{lung} + \dot{V}_{leak}. \quad [8]$$

$$Z_{lung} \cdot \dot{V}_{lung} = Z_{leak} \cdot \dot{V}_{leak}. \quad [9]$$

Solving [7] and [8] simultaneously,

$$V_{lung}(t) = \Delta\dot{V} \cdot R_{leak} \cdot C_{lung} (1 - e^{-t/[R_{lung} C_{lung} + R_{leak} C_{leak}]}). \quad [10]$$

Evaluation of 21 Passive Humidifiers According to the ISO 9360 Standard: Moisture Output, Dead Space, and Flow Resistance

Richard D Branson RRT and Kenneth Davis Jr MD

BACKGROUND: Humidification of inspired gases during mechanical ventilation is essential to maintain structure and function of the respiratory mucosa. Humidity has been most often provided by heated humidifiers. More recently passive humidifiers, (PH) or artificial noses, have been used in selected cases. We evaluated the moisture output of 21 passive humidifiers. DESCRIPTION OF DEVICE: Twenty-one PHs were studied including 11 hygroscopic condenser humidifiers (HCH), 7 hygroscopic condenser humidifier filters (HCHF), and 3 heat and moisture exchanger filters (HMEF). EVALUATION METHODS: All devices were tested for moisture output (mg H_2O/L), and resistance (cm $H_2O \cdot L \cdot s^{-1}$) according to International Standard Organization (ISO) 9360. Moisture output was measured by determining weight loss from a water bath during a 2-hour period of ventilation at 3 combinations of frequency (f) and tidal volume (V_T) (20 breaths/min at 500 mL, 10 breaths/min at 1,000 mL, and 20 breaths/min at 1,000 mL). Dead space was measured by measuring pressure change in the PH during delivery of volume from a calibrated syringe. Resistance was calculated by measuring pressure drop across the PH at a flow of 1 L/s. EVALUATION RESULTS: Moisture output ranged from 19.6 to 33.2 mg H_2O/L. As a group, HCHF performed better than HCHs and HMEFs. Dead space ranged from 19 to 94 mL. Resistance ranged from 0.7 to 3.5 cm $H_2O \cdot L \cdot s^{-1}$. CONCLUSIONS: The ISO 9360 system allows ranking of devices in terms of moisture output, dead space, and resistance. These values can all be integrated by the clinician to intelligently choose an appropriate PH. We caution that these results apply specifically to the conditions tested and that results obtained clinically will vary with patient variables, such as temperature and minute ventilation. [Respir Care 1996;41(8):736-743]

Introduction

Humidification of inspired gases during mechanical ventilation is a standard of care.[1] Investigators have described the untoward effects of dry gases on the structure and integrity of the respiratory system.[2-5] Yet, the optimum level of humidity remains elusive. Likewise, choosing a device that will provide optimum humidification is difficult. Heated humidification has been the most popular method for conditioning inspired gases in the intensive care unit (ICU). In the past decade, however, passive humidifiers (artificial noses) have gained acceptance for selected cases.[6-8]

An artificial nose is a device that collects the patient's expired heat and moisture in a medium and returns a portion of it during inspiration. The method used to retain and exchange heat and moisture allows these devices to be classified. The simplest devices use a medium that traps heat and

Mr Branson is Assistant Professor of Surgery, and Dr Davis is Associate Professor of Surgery and Anesthesia, Division of Trauma and Critical Care, Department of Surgery, University of Cincinnati Medical Center—Cincinnati, Ohio.

Correspondence: Richard D Branson RRT, Department of Surgery, University of Cincinnati Medical Center, 231 Bethesda Avenue, Room 2457, Cincinnati, OH 45267-0558.

moisture by physical principles alone. These are referred to as heat and moisture exchangers (HMEs) and were the first passive humidifiers. If an HME also contains a filter (F), it can be considered an HMEF. In an effort to improve the moisture-conserving properties of an HME, many manufacturers treat the medium with a hygroscopic salt (calcium or lithium chloride). These devices are called hygroscopic condenser humidifiers (HCH) and use both physical and chemical properties to retain and exchange moisture. An HCH with a filter is considered an HCHF.

Evaluations of HMEs and HCHs have been attempted both in vitro and in vivo.[9-14] In 1988, the International Standards Organization (ISO) developed a test method, ISO 9360, to evaluate HMEs and HCHs.[15] Eckerbom and Lindholm[16] published an evaluation of 6 devices using ISO 9360 in 1990. The results of this study helped to highlight some of the difficulties associated with the ISO 9360 test apparatus.

The purpose of our study was to evaluate a number of commercially available HMEFs, HCHs, and HCHFs and determine the moisture output, resistance, and dead space using the ISO 9360 test method. To our knowledge, independent testing of these devices using the same model and conditions has not been previously reported. This independent evaluation was undertaken to assist practitioners in comparing devices.

Materials & Methods

Device Description

Twenty-one passive humidifiers* were studied. Manufacturers were contacted by phone and by mail and asked to provide a minimum of 12 devices from their stock.

Testing Apparatus

We duplicated the lung model described in ISO 9360 which consists of a temperature-controlled Cascade-I humidifier, a set of 1-way valves, and 2 rubber test lungs (Fig. 1). Breathing was simulated with a Puritan Bennett 7200 ventilator and tidal volume (V_T) and minute volume ($\dot{V}_E$) were continuously monitored by a variable-orifice pneumotachometer connected to a respiratory monitor.

Gas from the ventilator at a fractional inspired oxygen concentration of 0.50 (temperature of 21° C and absolute humidity of < 1.0 mg H_2O/L) was delivered to the lung model at 1 of 3 respiratory frequency-tidal volume combinations as specified by ISO 9360. Table 1 lists the 3 ventilator settings. Gas traverses the pneumotachometer and is directed by 1-way valves into the test lungs. During simulated expiration, gas is forced by the test lungs through the tower of the heated

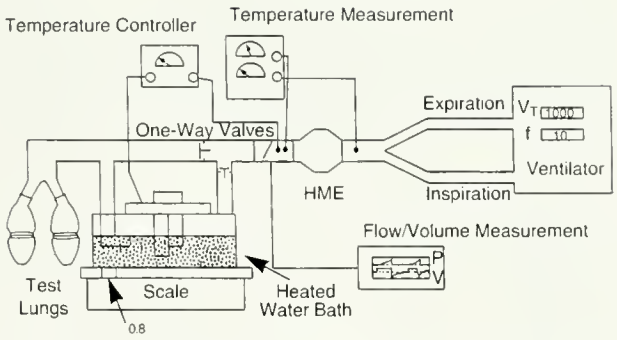


Fig. 1. ISO lung model for testing passive humidifiers; HME = heat and moisture exchanger.

humidifier, picking up heat and humidity for return into the ventilator circuit. The heating element of the humidifier is set at the highest setting and the power cord plugged into a servo-controlled temperature controller. A temperature probe placed between the model and the ventilator circuit monitors gas temperature. The temperature controller maintains expired gases at 34° C. This temperature is the temperature of expired gases measured at the teeth of intubated patients during surgery.[17] The temperature monitoring system used a temperature probe with an accuracy of ± 0.5° C and a 1-second response time (10-90% step change). Relative humidity of expired gases was checked at 30-minute intervals using an electronic hygrometer. The model delivers gases at 100% relative humidity, making continuous measurement impractical because once the sensor becomes saturated it displays 100% relative humidity until dried.

Table 1. The Three Ventilator Settings Used during Testing of Passive Humidifiers

Setting	Tidal Volume	Frequency (breaths/min)	Minute Ventilation	I Time*	E Time
I	500 mL	20	10 L	1.0	2.0
II	1,000 mL	10	10 L	2.0	4.0
III	1,000 mL	20	20 L	1.0	2.0

I Time = inspiratory time in seconds; E time = expiratory time in seconds.

The measurement of water loss in grams is the most important part of the ISO 9360 method. As long as this value is 37.6 ± 1 mg/H_2O/L, small errors in temperature and relative humidity output appear to balance out over the 2-hour period of measurement. The hygrometer was calibrated using known humidities created from solutions of lithium salts. According to ISO 9360, the ratio of inspiratory-to-expiratory time should be 1:2. In order to control expiratory flow, a linear resistor with a value of 20 cm $H_2O \cdot L \cdot s^{-1}$ was placed in the expiratory limb of the circuit. At a V_T of 1,000 mL and breathing rate of 10 this created an inspiratory time of 2.0 seconds (square flow wave-

*Suppliers of commercial products are listed in the Product Sources section at the end of the text.

form at 30 L/min) and an expiratory time of 4.0 seconds (exponential-decay flow waveform with a mean expiratory flow of 15 L/min). Figure 2 depicts the inspiratory and expiratory flow waveforms at 10 breaths/minute and V_T of 1,000 mL.

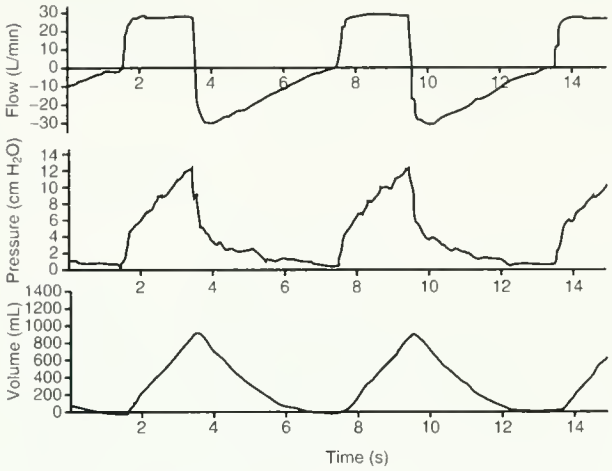


Fig. 2. Airway pressure and flow waveforms during ventilation of the lung model.

The entire test apparatus was placed on a precision scale with an accuracy of ± 0.1 gram. Every morning the apparatus heated for 2 hours prior to testing. This was followed by a 2-hour period during which the water loss in grams from the lung model was measured without a passive humidifier in-line. After the control period had been established, a passive humidifier was placed in-line between the model outlet and the ventilator circuit, and water loss over a 2-hour period was measured. Three units of each of the 21 devices were tested at each of the 3 ventilator settings. The ISO standard suggests that testing be accomplished for 24 hours. However, the results of Eckerbom and Lindholm[16] and of others[13,14] suggest that the maximum moisture output is achieved by the second hour of testing. Moisture output of each device was determined by the ISO 9360 formula:

$$\text{moisture output} = AH\left(1 - \frac{(H_2O \text{ loss with PH})}{H_2O \text{ loss without PH}}\right)\left(\frac{V_2}{V_1}\right)$$

where AH = absolute humidity at 34° C and 100% relative humidity, or 37.6 mg H_2O/L, V_1 is the inspired volume of gas during the testing period, PH is passive humidifier, and V_2 is the expired volume of gas during the testing period.

The water loss and volume data allow an efficiency to be calculated, which is multiplied by the absolute humidity of expired gas to determine the moisture returned to the patient.

Measurement of Dead Space & Resistance

Prior to use and after 2 hours in the lung model, resistance of each device was measured. Air at 1 L/s was directed through a rotameter to measure flow. Pressure drop across the device was measured by an RT-200 calibration analyzer.

Dead space was measured according to ISO 9360. Each device was capped at one end. The other end of the device was connected to a calibration syringe with a pressure tap attached to a pressure transducer. The calibration syringe was opened to a value that when added to the test system would increase pressure to at least 50 cm H_2O. The volume of the syringe was than emptied into the system and the resulting pressure measured. This was repeated with the passive humidifier out of the system to account for dead space due to system components. Dead space or compressible volume (V_c) is then determined by the following equation:

$$V_c = P_{atm}\left(\frac{\Delta V_1}{\Delta P_1} - \frac{\Delta V_2}{\Delta P_2}\right),$$

where P_{atm} is atmospheric pressure, V_1 is the volume delivered from the syringe, P_1 is the pressure in the system when V_1 is delivered, V_2 is the volume added from the syringe without the passive humidifier in-line, and P_2 is the resulting pressure.

All measurements were accomplished using passive humidifiers that had not been used in the lung model (ie: they were dry).

Results

The moisture output at each of the 3 respiratory frequency-tidal volume combinations for the devices tested are shown in Table 2. At a breathing frequency of 20 f and V_T of 500 mL, 10 of the devices tested were able to deliver 30 mg H_2O/L. At a breathing rate of 10 and V_T of 1,000 mL, only 6 devices delivered 30 mg H_2O/L. There was a trend for devices to deliver higher humidity when V_T and $\dot{V}_E$ were less. As a group, the HCHF devices performed better with regard to moisture output than did the HMEF devices.

Resistance (pressure drop at 1 L/s) is shown in Table 2. Resistance ranged from 0.7 cm $H_2O \cdot L \cdot s^{-1}$ to 3.5 cm $H_2O \cdot L \cdot s^{-1}$. HCHF devices tended to have higher resistances than HMEF devices; both were higher than HCH devices. Dead space and resistance had no consistent correlation. After 2 hours of use in the lung model, resistance increased slightly in all devices.

Dead space for the devices are shown in Table 2. The dead space ranged from a minimum of 10 mL to a maximum of 94 mL. Among HCHF devices, an increase in dead space was associated with an increase in moisture output. The HMEF devices also increased moisture output as dead space increased, but the moisture output was considerably less than the output of HCH devices.

Table 2. Moisture Output, Resistance, Dead Space, and Moisture Output/mL of Dead Space of 21 Passive Humidifiers (PH), Obtained with Testing Apparatus Recommended by the ISO

Device	Type of PH	Moisture Output (mg H_2O/L)			Resistance cm $H_2O \cdot L \cdot s^{-1}$ @ 1 L/s		Dead Space (mL)	Moisture Output/mL of Dead Space
		500 × 20	1,000 × 10	1,000 × 20	Before	After		
Aqua H	HCH	31.2 (0.7)*	28.3 (0.5)	27.1 (0.9)	0.9 (0.1)	1.2 (0.2)	84 (7)	0.37
Aqua FH	HCHF	31.8 (0.3)	29.1 (0.4)	27.4 (0.4)	1.62(0.2)	1.78 (0.3)	87 (5)	0.36
ARC	HCH	32.0 (0.6)	31.4 (0.7)	30.4 (0.7)	0.7 (0.1)	1.1 (0.2)	89 (6)	0.36
ARCF	HCHF	32.4 (0.5)	32.0 (0.6)	30.6 (0.8)	2.0 (0.2)	2.2 (0.3)	86 (7)	0.38
Edith	HCH	30.6 (0.4)	30.0 (0.3)	28.9 (0.4)	1.48(0.4)	1.54 (0.2)	82 (5)	0.37
Engström 500	HCH	26.7 (0.3)	25.1 (0.4)	24.9 (0.6)	1.60(0.8)	1.8 (0.5)	19 (3)	1.43
Engström 1000	HCH	27.4 (0.5)	26.1 (0.8)	25.8 (0.7)	2.0 (0.6)	2.1 (0.3)	29 (5)	0.94
Engström 1500	HCH	29.1 (0.9)	28.4 (0.6)	26.5 (0.7)	3.5 (0.5)	3.67 (0.4)	40 (6)	0.73
FloCare "L"	HCH	30.4 (1.1)	27.1 (0.9)	25.6 (0.7)	1.6 (0.2)	1.78 (0.6)	32 (5)	0.95
Gibeck HVF	HCHF	32.1 (0.9)	30.8 (0.7)	29.7 (0.6)	2.2 (0.4)	2.36 (0.5)	58 (7)	0.34
Hygrobac	HCHF	32.5 (0.6)	31.0 (0.5)	29.4 (0.4)	1.9 (0.1)	2.08 (0.6)	92 (9)	0.35
Hygrobac S	HCHF	29.6 (0.5)	28.0 (0.6)	26.8 (0.3)	2.4 (0.5)	2.57 (0.7)	48 (5)	0.62
Hygroster	HCHF	33.2 (0.2)	31.9 (0.6)	30.6 (0.8)	2.5 (0.4)	2.7 (0.6)	94 (7)	0.35
Intersurgical	HMEF	25.4 (0.5)	22.6 (0.4)	21.8 (0.6)	2.2 (0.1)	2.3 (0.2)	65 (3)	0.39
Intertech 2841	HCH	28.5 (0.6)	27.0 (0.6)	25.5 (0.6)	1.75(0.4)	1.84 (0.9)	36 (4)	0.79
Intertech HEPA	HMEF	24.8 (0.6)	23.6 (0.2)	21.1 (0.3)	1.6 (0.4)	1.79 (0.7)	78 (8)	0.32
Pall	HMEF	24.9 (0.6)	21.2 (0.4)	19.6 (0.3)	2.2 (0.3)	2.38 (0.6)	90 (5)	0.28
Portex 600	HCH	25.2 (0.2)	24.6 (0.3)	22.4 (0.4)	2.7 (0.4)	2.86 (0.2)	10 (2)	2.52
Portex 1200	HCH	27.2 (0.1)	26.4 (0.5)	25.1 (0.6)	1.3 (0.2)	1.5 (0.2)	33 (2)	0.82
Vital Signs HCH	HCH	30.8 (0.6)	28.5 (0.3)	28.1 (0.6)	2.3 (0.3)	2.44 (0.5)	48 (4)	0.64
Vital Signs HCHF	HCHF	29.7 (0.4)	28.0 (0.5)	26.9 (0.2)	2.5 (0.5)	2.67 (0.4)	58 (3)	0.51

*Mean (SD)

The bias and precision of the test method under the described conditions are 1.1 mg H_2O/L and 0.3 mg H_2O/L.

Discussion

Our results confirm those of Eckerbom and Lindholm[16] and those published by the Medical Devices Directorate (MDD).[18] In our study, we found that HCHs are superior to HMEFs with regard to moisture output (mean HMEF moisture output was 20.8 mg H_2O/L while mean HCH output was 27.3 mg H_2O/L at a V_T of 1,000 mL and f of 20). Mean resistance at a flow of 1 L/s was 2.16 cm $H_2O \cdot L \cdot s^{-1}$ for HCHF, 2.0 cm $H_2O \cdot L \cdot s^{-1}$ for HMEF, and 1.8 cm $H_2O \cdot L \cdot s^{-1}$ for HCH. Moisture output of all devices is greater at lower V_T and $\dot{V}_E$. (At the ventilator settings explained in Table 1, we calculated a mean moisture output at Setting I to be 29.3 mg; at Setting II, 27.6 mg; and at Setting III, 24.9 mg H_2O.) Resistance increases slightly in all devices after use (mean increase of 0.18 cm $H_2O \cdot L \cdot s^{-1}$ after 3 hours of use), and performance of HCH devices tends to improve as dead space of the device increases.

The ISO 9360 system serves as a method to compare similar devices under controlled conditions. However, the actual moisture delivered to a patient will depend upon the temperature of gas entering the artificial nose, the V_T, and $\dot{V}_E$. A patient with a body temperature of 32° C (ie, a hypothermic patient) cannot receive 32 mg H_2O/L from an artificial nose. At 32° C, the absolute humidity of expired gas could only be 34 mg H_2O/L. If the passive humidifier is 80% efficient, than delivered moisture would only be 27.2 mg H_2O/L. We believe that the ISO 9360 test is simply a ranking system for passive humidifiers; it does not define the moisture output of these devices under all clinical conditions. We also believe that the type of humidifier used should be based upon patient condition, duration of ventilatory support, goal of humidity therapy, and ventilator settings.[6]

Eckerbom and Lindholm[16] have commented on a few of the difficulties associated with the ISO 9360 test apparatus. We have also identified several possible sources of error. Of particular interest is the shape and rate of expiratory flow. ISO 9360 states that the I:E be 1:2. At a breathing rate of 10 f and V_T of 1,000 mL, this results in an inspiratory time of 2.0 seconds (square flow waveform of 30 L/min) and an expiratory time of 4.0 seconds. Depending upon the compliance of the test lungs and total system resistance, this could result in an expiratory flow for 4.0 seconds (mean expiratory flow of 15 L/min), an expiratory flow for 2.0 seconds (mean expiratory flow of 30 L/min) with a 2-second pause, or an expiratory flow for 1.0 second (mean expiratory flow of 60 L/min) with a 3-second pause. These 3 expiratory-flow conditions will result in 3 different moisture-output values. Our experience suggests that as expiratory flow increases and contact time between expiratory gas and the HME diminishes, so does moisture output. In a comparative evaluation, consistency is of primary importance. We chose to allow a 4.0-second expiratory time to allow comparison to the MDD

evaluations. However, the MDD uses a microprocessor-controlled piston to create inspiratory and expiratory flow and uses a square flow waveform on both inspiration (30 L/min) and expiration (15 L/min).[18] Our decelerating expiratory-flow waveform is more representative of the clinical situation and results in slightly lower values than those reported by the MDD.

Dead space of the test apparatus is also important. In this instance, dead space is the volume between the output of the 34° C expired gas and the passive humidifier. If this volume is too large it serves to act as a secondary source of heat and moisture exchange. The dead-space volume of our system was 32 mL. We believe any volume greater than 10% of the V_T will result in erroneous values. These variables, as well as accuracy of temperature measurement and resolution of the temperature controller, all help to explain the wide differences in study results among investigators using the ISO 9360 test apparatus.

Published results using ISO 9360 include those of Eckerbom and Lindholm,[16] the MDD reports,[18] and our data. The values for moisture output of devices common to the 3 studies are shown in Table 3. The results published by the MDD and our results are within 2 mg H_2O/L for each device. Our results and those of Eckerbom and Lindholm are similar for 2 of the 3 common devices. The results related to the Engström Edith by Eckerbom and Lindholm are suspect, being nearly 9 mg H_2O/L less than ours and the MDD. This underscores the importance of multiple trials, validation of the test apparatus, and use of the reported data as a ranking system. Of note from the Eckerbom and Lindholm paper, is the control value (the test apparatus run without a passive humidifier), which is reported as 10 mg H_2O/L (water loss of 27.4 mg H_2O/L). This value should be 37.6 mg H_2O/L and suggests possible technical problems with the test apparatus. However, despite this error, 2 of the 3 results they report are similar to ours.

Table 3. Comparison of Moisture Output Results from the Present Study and Two Previous Reports (Tidal Volume 1.0 L and Respiratory Frequency of 10 Breaths/Min)

Device	Eckerbom et al[16]	MDD[18]	Branson et al
Pall	20.9*	21.1	21.2
Edith	21.5	31.8	30.0
Vital Signs HCH	27.8	—	28.0
Vital Signs HCHF	—	—	28.5
Engström 1000	—	26.8	26.1
Engström 1500	—	29.7	28.4
Hygrobac	—	30.9	31.0
Gibeck Humid Vent Filter	—	31.5	30.8
Intersurgical	—	22.0	22.6
ARC Thermoflo Filter	—	32.1	32.0

*Values are mg H_2O/L

According to ISO 9360, pressure drop across a passive humidifier should be less than 5.0 cm H_2O at a flow of 50 L/min.[15] All of the devices we tested met this criterion. It is our own opinion that the resistance of a passive humidifier should mimic normal upper airway resistance and should therefore be less than 3.0 cm $H_2O \cdot L \cdot s^{-1}$ (pressure drop of 3.0 cm H_2O at a flow of 60 L/min). Only the Engström Edith 1500 exceeded this value (3.5 cm $H_2O \cdot L \cdot s^{-1}$). The importance of passive humidifier resistance depends on the clinical situation. In the operating room where patients are often heavily sedated and/or paralyzed, resistance may be of little importance. In the ICU, flow resistance may contribute to an already increased work of breathing and should be avoided. In pediatric environments, the resistance value should, of course, be adjusted.

Passive humidifier resistance is a function of density of the medium, connector sizes (diameter), path of gas flow, and dead space. An increase in dead-space volume allows for a lower resistance and to some extent a higher moisture output. However, the balance between resistance and dead space must be considered. Of the devices we tested, 8 had a dead space > 80 mL and 3 had a dead space > 90 mL. At a tidal volume of 500 mL, this results in a clinically important increase in total dead space. (Nearly 20% of the V_T is lost in the passive humidifier.) Device selection should include consideration of the dead space of the device with respect to the set V_T. Additionally, spontaneously breathing patients may find the additional dead space an unnecessary burden, possibly prolonging weaning or contributing to muscle fatigue.[19-22] We recommend a passive humidifier with a dead space < 15% of the set V_T and in spontaneously breathing patients a device with a dead-space volume of < 10% of the spontaneous V_T.

Previous evaluations of passive humidifiers have used electronic hygrometers and thermistors to measure relative humidity and temperature separately to determine absolute humidity.[10-14] This has been accomplished in bench and human studies. An important limitation to this method is related to the response time of the separate measuring devices and matching signals. Electronic hygrometers generally have a slow response time (0-90% in 4 s) while thermistors are much faster (0-90% in 0.5 s). If during measurement, the peak temperature and peak humidity are reported but occur at separate times within inspiration, then the reported value for absolute humidity is an overestimate. Likewise, if trough levels are reported, moisture output is underestimated. This problem coupled with the bidirectional gas flow within the system and the effects of condensation on the accuracy and response time of the sensors makes electronic measurement of humidity difficult. Primiano et al[23] adapted a mass spectrometer to measure the partial pressure of water vapor in respired gases to eliminate these problems. However this technique is not widely available.

Numerous evaluations of passive humidifiers have been published, but the differences in methodology make comparison of results difficult. Table 4 lists bench evaluations of passive humidifiers including methodology, year of publication, and applicable results.

Table 4. Published Bench Evaluations of Passive Humidifiers

Author	Year	Measurement System	Ventilation Parameters	Devices and Results (mg H_2O/L)	Expired Gas Temperature °C
Walker et al[11]	1976	Gravimetry (water loss by weight)	Room air f + V_T = NR	Dameca = 20.4, Portex = 20.4 Garthur = 17	34.5
Gedeon et al[29]	1979	Thermometry + hygrometry	NR, f + V_T = varied	Siemens 150 = 32 @ 1.0 L V_T	NR water bath = 37
Weeks[12]	1981	Thermometry + hygrometry	Room air 8 × 800 mL	Siemens 150 = 30	32-34
Mebius[13]	1983	Thermometry + hygrometry and gravimetry	Air NR × 500 mL	Edith = 29, HumidVent 1 = 26, Siemens 150 = 30, Siemens 151 = 27, Breathaid = 22	33.5(0.5)
Health Devices[32]	1983	Thermometry + hygrometry	Air 10 × 1,000 mL	Dameca = 16, HumidVent = 21, Siemens 150 = 25, Breathaid = 14	30
Chalon et al[30]	1984	Thermometry + hygrometry	Circle absorber system including CO_2 production 10 × 600 mL	Pall = 27	32(0.1)
Ogino et al[31]	1985	Gravimetry	Air 10 × 700 mL	Portex HV = 19.3, Siemens 150 = 21, Siemens 151 = 14, Breathaid = 10	37(0.1)
Shelly et al[10]	1986	Gravimetry	Room air, anesthesia circuit	*Edith, Garthur, Portex, Siemens 150, Pall	34.5
Branson et al[9]	1987	Thermometry + hygrometry	Air 12 × 1,000 mL	Edith = 26.5, Foam Nose = 24, Pall = 24, Breathaid = 21, Siemens 150 = 26.5, HumidVent = 23.5, Humidair = 25	32(1.0)
Hayes[14]	1987	Thermometry + hygrometry	Air $\dot{V}_E$ = 10 L/min	Edith = 28, HumidVent = 26, Foam Nose = 25, Pall = 20, ICOR 101 = 24, ICOR 102 = 22, Siemens 150 = 26, Siemens 151 = 28	NR
Cigada et al[26]	1990	Thermometry + hygrometry	Air 15 × 800 mL	Pall = 15.7, Breathaid = 14, Edith = 17, HumidVent = 16, HumidVent 2 = 20, Hygrobac = 21, SH 152 = 20, ICOR = 13	30-33
Eckerbom et al[16]	1990	Gravimetry	Air 10 × 1,000 mL	Pall = 20.9, Foam Nose = 24.2, Servo 150 = 26.6, Edith = 21.5, ICOR = 27.8, Humid Vent = 19.2	34(0.6)
Mebius[27]	1992	Thermometry + hygrometry and gravimetry	Air 10 × 1,000 mL	HumidVent = 29.9, Pall = 22, ARC = 29.9, Hygrobac = 29.9, ICOR = 29.9, Intersurgical = 22	34
Unal et al[28]	1995	Thermometry and mass spectometry	Air 10 × 1,000 mL	Hygroster = 34	34.5(1.0)

NR = not reported, f = frequency, V_T = tidal volume, $\dot{V}_E$ = expired volume per minute.
* All values are reported in water loss (g H_2O/h), not moisture output.

Comparisons of passive humidifiers are difficult. Moisture output is an important consideration—but not the only important feature of a humidifier. In fact, moisture output can be examined in other ways than the absolute value. Table 2 shows the moisture output of these devices/mL of dead space. This provides a method of viewing passive humidifiers using 2 of the 3 most important characteristics, moisture output, and dead space. Of note is the fact that smaller devices can pro-

vide more moisture/mL of dead space, but in order for an HCH to reach the 30 mg H_2O/L threshold, dead space must approach 60 mL.

The Consensus Statement on Mechanical Ventilation of the American Association for Respiratory Care suggests that delivered humidity should be 25-35 mg H_2O/L.[24] This differs from the 30 mg H_2O/L often quoted as a minimum. That quoted value comes from the American Society for Testing and Materials standard for heated humidifiers.[25] We believe that using the 30-mg value is a misapplication of the standard. The Consensus Conference value allows the use of passive humidifiers under certain conditions. We have published an algorithm for the appropriate use of passive humidifiers in the ICU and validated its use in 100 patients without incidence of endotracheal tube occlusion.[6] We believe that appropriate application is paramount to successful use of passive humidifiers. In several clinical studies, endotracheal tube occlusion has been common. This has been attributed to use of an HMEF that performed poorly in all three ISO 9360 evaluations. In 1995, Dreyfuss et al[8] reported the use of an HCHF in ICU patients with an incidence of endotracheal tube occlusion of 2% (1/61). However, Dreyfuss also reported that occlusion of the PH occurred 6 times in 4 patients—10% (6/61). This further supports the need for use of an algorithm to prevent use of passive humidifiers in instances in which they are likely to cause complications.[6] Any cost savings derived from use of passive humidifiers will be eliminated by a single endotracheal tube occlusion resulting in patient morbidity.

We believe that there are 6 important characteristics of a passive humidifier: moisture output, dead space, resistance, cost, filtration, and design (shape, weight, and features such as a port for carbon dioxide sampling). In the ICU, we believe the most important characteristics are moisture output, dead space, resistance, and cost. Filtration has not shown to be of value in the ICU,[33,34] and design is a matter of preference. However, size, weight, and PH features (sampling port, extension tube) may play a role in choosing a PH. The absolute level of humidity required for ICU use is uncertain. We believe that the difference between a device that delivers 28 mg H_2O/L and one that delivers 32 mg H_2O/L (according to ISO 9360) is unimportant given the accuracy of the test results and the small difference in delivered humidity. In these instances, the device with a moisture output > 28 mg H_2O/L and the lowest resistance and dead space should be chosen. Cost is also an important issue, and we believe that purchase of a device that costs an extra 75 cents to gain 1-2 mg H_2O/L is unwise. The desired characteristics of a passive humidifier change with the clinical situation (in the operating room where ventilation will last < 2 hours, cost may be the most important determinant). We continue to use passive humidification for all ventilated patients in the recovery room and cardiac surgery ICU. Use of passive humidifiers in the medical and surgical ICUs is controlled by the algorithm and limited to a maximum of 5 days.

In summary, we evaluated 21 passive humidifiers using ISO 9360 test methods for moisture output, resistance, and dead space. This evaluation is intended to allow ranking of devices according to these characteristics. For ICU use, we recommend a passive humidifier with a moisture output of > 28 mg H_2O/L, dead space < 50 mL, and resistance < 2.5 cm $H_2O \cdot L \cdot s^{-1}$. We also recommend using an algorithm to select patients for the type of humidification and limiting use to < 5 days. Passive humidifiers always result in water loss from the respiratory tree and cannot add moisture to already thickened secretions. In cases of hypothermia (< 32° C), bloody or thickened secretions, and air leaks, a heated humidifier should be used.[6]

ACKNOWLEDGMENT

The authors are grateful for sponsorship of the study by the following manufacturers: Hudson RCI, Gambro Engström, FloCare, Mallinckrodt, Intersurgical, SIMS Industries, ARC Medical, and Vital Signs.

PRODUCT SOURCES

Passive Humidifiers:
Aqua + H and Aqua + FH, Hudson RCI, Temecula CA
Edith, Edith 500, Edith 1000, and Edith 1500, Gambro-Engström, Roslyn Heights NY
FloCare "L", FloCare Inc, Wayne PA
Gibeck HVF, Gibeck-Dryden, Indianapolis IN
Hygrobac, Hygrobac "S", and Hygroster, Mallinckrodt, St Louis MO
Intersurgical HME, Intersurgical, Liverpool NY
Intertech 2841 and Intertech HEPA, Intertech, Lincolnshire IL
Pall HME, Pall Biomedical, Glen Cove NY
Portex 600 and Portex 1200, Sims Industries, Lincolnshire IL
Thermoflo Filter and Thermoflo, ARC Medical, Atlanta GA
Vital Signs HCH and Vital Signs HCHF, Vital Signs, Totowa NJ

Humidifier:
Cascade I, Puritan Bennett, Carlsbad CA

Hygrometer:
Viasala HMI 32, Woburn MA

Temperature Controller:
Servo-Pak, Isothermal Systems Inc, Riverside CA

Respiratory Monitor:
Bicore CP-100, Allied Medical Products, Riverside CA

Ventilator:
Puritan Bennett 7200ae, Puritan Bennett, Carlsbad CA

Test Lungs:
Test lung, Puritan Bennett, Carlsbad CA

Linear Resister:
Linear Resister, Michigan Instruments, Grand Rapids MI

Electronic Balance:
FX-3000, A+D Co Ltd, Tokyo Japan

Calibration Analyzer:
RT-200, Timeter Corp, Lancaster PA

REFERENCES

1. American Association for Respiratory Care. Clinical practice guideline: humidification during mechanical ventilation. Respir Care 1992; 37(8):887-890.
2. Tsuda T, Noguchi H, Takumi Y, Aochi O. Optimum humidification of air administered to a tracheostomy in dogs. Scanning electron microscopy and surfactant studies. Br J Anaesth 1977;49(10):965-977.
3. Fonkalsrud EW, Sanchez M, Higashijima I, Arima E. A comparative study of the effects of dry vs humidified ventilation on canine lungs. Surgery 1975;78(3):373-380.
4. Hirsch JA, Tokayer JL, Robinson MJ, Sackner MA. Effects of dry air and subsequent humidification as tracheal mucous velocity in dogs. J Appl Physiol 1975;39(2):242-246.
5. Marfatia S, Donahoe PK, Hendren WH. Effect of dry and humidified gases on the respiratory epithelium in rabbits. J Pediatr Surg 1975;10(5):583-592.
6. Branson RD, Davis K, Campbell RS, Johnson DJ, Porembka DT. Humidification in the intensive care unit: prospective study of a new protocol utilizing heated humidification and a hygroscopic condenser humidifier. Chest 1993;104(6):1800-1805.
7. Sottiaux T, Mignolet G, Damas P, Lamy M. Comparative evaluation of three heat moisture exchangers during short term postoperative mechanical ventilation. Chest 1993;104(1):220-224.
8. Dreyfuss D, Djedaini K, Gros I, Mier L, Le Bourdelles G, Cohen Y, et al. Mechanical ventilation with heated humidifiers or heat and moisture exchangers: effects on patient colonization and incidence of nosocomial pneumonia. Am J Respir Crit Care Med 1995;151(4):986-992.
9. Branson RD, Hurst JM. Laboratory evaluation of moisture output of seven airway heat and moisture exchangers. Respir Care 1987; 32(9):741-747.
10. Shelly M, Bethune DW, Latimer RD. A comparison of five heat and moisture exchangers. Anaesthesia 1986;41(5):527-532.
11. Walker AK, Bethune DW. A comparative study of condenser humidifiers. Anaesthesia 1976;31(8):1086-1093.
12. Weeks DB, Ramsey FM. A laboratory investigation of six artificial noses for use during endotracheal anesthesia. Anesth Analg 1981;62:758-763.
13. Mebius C. A comparative evaluation of disposable humidifiers. Acta Anaesthesiol Scand 1983;27(5):403-409.
14. Hayes B. Evaluation report: Heat and moisture exchangers. J Med Eng Technol 1987;11:117-127.
15. International Organization for Standardization. Anaesthetic and respiratory equipment. Heat and moisture exchangers for use in humidifying respired gases in humans, 1st ed. ISO International Standard 9360, 1992.
16. Eckerbom B, Lindholm CE. Performance evaluation of six heat and moisture exchangers according to the Draft International Standard (ISO/DIS 9360) Acta Anaesthesiol Scand 1990;34(5):404-409.
17. Dery R, Pelletier J, Jaques A, Clavet M, Houde JJ. Humidity in anesthesiology. 3: Heat and moisture patterns in the respiratory tract during anesthesia with the semi-closed system. Can Anaesth Soc J 1967; 14(4):287-298.
18. Department of Health, Scottish Home and Health Department, Welsh Office and Department of Health and Social Services (Northern Ireland). Medical devices directorate evaluation #63, 93, 102, 103, 109, 110, 111, 113, 141, 142, 148, 151, 152, 155, 189, 190.
19. Ploysongsang Y, Branson RD, Rashkin MC, Hurst JM. Effect of flowrate and duration of use on the pressure drop across six artificial noses. Respir Care 1989;34(10):902-907.
20. Nishimura M, Nishijima MK, Okada T, Taenaka N, Yoshiya I. Comparison of flow-resistive work load due to humidifying devices. Chest 1990;97(3):600-604.
21. Manthous CA, Schmidt GA. Resistive pressure of a condenser humidifier in mechanically ventilated patients. Crit Care Med 1994;22(11): 1792-1795.
22. Chiaranda M, Verona L, Pinamonti O, Dominioni L, Minoja G, Conti G. Use of heat and moisture exchanging (HME) filters in mechanically ventilated ICU patients: influence on airway flow-resistance. Intensive Care Med 1993;19(8):462-466.
23. Primiano FP, Moranz ME, Montague Jr FW, Miller RB, Sachs DPL. Conditioning of inspired air by a hygroscopic condenser humidifier. Crit Care Med 1984;12(8):675-678.
24. Branson RD, Brougher P, Chatburn RL, East TD, Marini JJ, MacIntyre NR. Consensus statement on the essentials of mechanical ventilators. Respir Care 1992;37(9):1000-1008.
25. American National Standards Institute. American national standards for breathing machines and their use. ANSI 1978;79.9-1979.
26. Cigada M, Elena A, Solca M, Damia G. The efficiency of twelve heat and moisture exchangers: An in vitro evaluation. Int Care World 1990;7:98-101.
27. Mebius C. Heat and moisture exchangers with bacterial filters: a laboratory evaluation. Acta Anaesthesiol Scand 1992;36(6):572-576.
28. Unal N, Pompe JC, Holland WP, Gultuna I, Huygen PE, Jabaaij K, et al. An experimental set-up to test heat-moisture exchangers. Intensive Care Med 1995;21(2):142-148.
29. Gedeon A, Mebius C. The hygroscopic condenser humidifier, A new device for general use in anaesthesia and intensive care. Anaesthesia 1979;34(10):1043-1047.
30. Chalon J, Markham JP, Ali MM, Ramanathan S, Turndorf H. The Pall Ultipor breathing circuit filter—an efficient heat and moisture exchanger. Anesth Analg 1984;63:566-570.
31. Ogino M, Kopotic R, Mannino FI. Moisture-conserving efficiency of condenser humidifiers, Anaesthesia 1985;40(10):990-995.
32. ECRI. Heat and moisture exchangers: health devices. 1983;12:155-166.
33. Dreyfuss D, Djedaini K, Gros I, Mier L, Bourdelles G, Cohen Y, et al. Mechanical ventilation with heated humidifiers or heat and moisture exchangers: effects on patient colonization and incidence of nosocomial pneumonia. Am J Respir Crit Care Med 1995;151(4): 986-992.
34. Djedaini K, Billiard M, Mier L, Bourdelles G, Brun P, Markowicz P, et al. Changing heat and moisture exchangers every 48 hours rather than 24 hours does not affect their efficacy and the incidence of nosocomial pneumonia. Am J Respir Crit Care Med 1995;152(5): 1562-1569.

Reflecting on 40 Years of RESPIRATORY CARE:

Looking Ahead

An excerpt from the opening address delivered at the 1955 Institute by the Chairman of the Board of Directors, Sister M. Rudolpha, O.S.F.

I am happy, once again, to preside at the opening luncheon of the Institute sponsored by the American Association of Inhalation Therapists.

I am happy that so many of you were able to come to this Institute. It is my hope that we shall continue to hold these annual meetings, and that because of them our influence will increase, and we shall earn not only the respect but the admiration of doctors, hospital administrators, and other professional people.

To accomplish this, I ask that all of us cooperate to the fullest degree with our Board of Directors; that we give all the help we can to our Executive Director. His job is to make our association grow on a national basis, and he will not be able to do this if we are non-cooperative, petty, jealous and opinionated. There are so many problems confronting us still. I would not want any of you to get the impression that this association is now an accomplished fact.

We have only begun to scratch the surface. When we consider that we have fewer than four hundred members, and that our potential membership can be estimated in the thousands—then we can readily see how much remains to be accomplished.

But it cannot be accomplished unless we each resolve to do our utmost to help. There are many ways. For example, have you ever told other people about our association? I do not mean only other therapists, but hospital personnel in other work areas. Why should they not know all about us? Who we are? What our work is? And what we hope to accomplish through this association? They are fully aware of other professional groups, such as Medical Record Librarians, Nursing Anesthetists, etc.

You can also help by getting new members. In her news letter, Sister Borromea asked that each of us get one prospective member to send in an application for membership. Some of us have already done this. But if we all make this effort, we shall, provided the applicant meets our standards, double our membership.

Not only will this be helpful financially, but it will help boost our morale. Moreover, it will let others know that we are a growing and dynamic organization.

I have a picture in my mind for the future. Perhaps it is only a dream, but who can tell when dreams become reality?

I see our association with chapters in principal cities all over the United States and Canada.

I see our membership in the thousands.

I visualize the respect and admiration with which others will regard us.

I see a Journal published regularly by our association, one very much in demand by all persons interested in inhalation therapy.

Other parts of this dream include a complete and competent bibliography, a permanent library containing the best that has been published on inhalation therapy.

Perhaps we shall even get to the place where we have licensing in all states, with uniformly high standards established with the help of our association. And, finally, I see industry looking to us with respect and with a great degree of satisfaction because we are a thoroughly self-supporting, and completely professional association.

These are just some of the dreams for the future of the American Association of Inhalation Therapists. Won't you please join me and the other members of the Board in working hard to help these dreams come true? [Respir Care 1956;1(1):7-8]

Editor's Note: In 1955, Sister Rudolpha had some interesting dreams—most of them have become realities. RESPIRATORY CARE is celebrating 40 years of publication, membership in the American Association for Respiratory Care (formerly, the American Association for Inhalation Therapy) is approaching 40,000, most states have licensing requirements for respiratory care practitioners, and the AARC is affiliated with associations worldwide. In the June 1996 issue of the Journal, Dean Hess PhD RRT published *The Program Committee Lecture: Respiratory Care at the Crossroads—Evolution or Extinction?* [Respir Care 1996;41(6):534-543]. The Lecture, delivered during the 1995 Annual Meeting in Orlando, Florida, provides a unique perspective about what the future looks like for today's respiratory care practitioner.

PFT Corner #53—Lessons from Spirometry: Look at the Picture

Matthew Veatch BS, Jack Wanger RPFT RRT, and Edward Chan MD

Case Summary

A 44-year-old woman who had been diagnosed with asthma 3 years earlier was seen in our outpatient clinic for a second opinion regarding her illness, which has been marked by frequent and prolonged hospitalizations and corticosteroid usage. At the time of her clinic visit, she was taking inhaled albuterol (4 puffs, 4 times/day), theophylline (200 mg, 2 times/day) and prednisone (20 mg/day). She said she had never smoked. She complained of marked dyspnea and a dry cough, which was triggered by exertion and by laughing or talking excessively. Auscultation of the upper lung fields revealed harsh, stridorous inspiratory breath sounds. In addition, she had signs of prolonged steroid usage, including abnormal fat distribution, myopathy, and bruising.

Pulmonary function tests were performed and the results are shown in Table 1 and Figure 1.

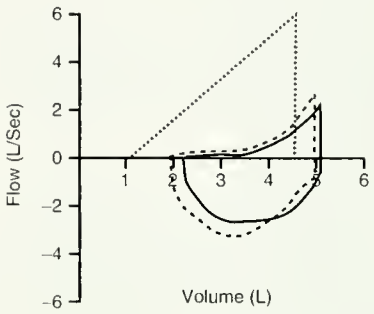


Fig. 1. Flow-volume loop obtained during initial spirometry in a 44-year-old woman who did not smoke but who was complaining of dyspnea and a dry cough (— = before bronchodilator; - - - = after bronchodilator; ..... = predicted).

Table 1. Results of Pulmonary Function Testing before and after Administration of Bronchodilator (0.5 mL Albuterol in 1.0 mL Physiologic Saline) to Patient with Dyspnea and Cough.

	Before (% Predicted)	After	% Change
Slow vital capacity, SVC (L)	3.54 (101)	3.31	5
Forced vital capacity, FVC (L)	3.03 (87)	3.14	4
Forced expiratory volume in the first second, FEV_1 (L)	0.99 (34)	0.96	−3
FEV_1/FVC (%)	33 (40)	31	−6
Forced expiratory flow between 25 & 75% of VC, $FEF_{25-75\%}$ (L/s)	0.69 (21)	0.67	−3
Peak expiratory flow, PEFR (L/s)	2.16 (37)	2.55	18
FEF at 25 % of VC, $FEF_{25\%}$ (L/s)	1.18 (21)	0.61	−48
FEF at 50% of VC, $FEF_{50\%}$ (L/s)	0.11 (2)	0.15	36
FEF at 75% of VC, $FEF_{75\%}$ (L/s)	0.20 (8)	0.23	15
Thoracic gas volume, TGV at functional residual capacity FRC (L)	2.99 (118)	2.78	−7
Residual volume, RV (L)	1.55 (144)	1.60	3
Total lung capacity, TLC (L)	5.09 (112)	4.92	−3
Airways resistance, R_{aw} (cm $H_2O \cdot L \cdot s^{-1}$)	4.71 (332)	5.24	11
Specific conductance, SG_{aw} ($L/cm\ H_2O \cdot L \cdot s^{-1}$)	0.05 (18)	0.06	20
Diffusing capacity, DLCO (mL/min/torr)	27.77 (105)		

The authors are associated with the Departments of Medicine and Pulmonary Physiology, National Jewish Center for Immunology and Respiratory Medicine and the Division of Pulmonary Sciences and Critical Care Medicine, University of Colorado Health Sciences Center, Denver, Colorado.

Reprints: Matthew Veatch, Pulmonary Physiology Unit, National Jewish Center for Immunology and Respiratory Medicine, 1400 Jackson St, Denver CO 80206.

How would you answer these questions?

What interpretation do you place on the results of the pulmonary function tests? _____

_____

If further testing is indicated, what other tests would you suggest? _____

_____

Answers and Discussion on page 746

Answers

PFT Interpretation: Pulmonary function studies (Table 1) reveal airflow limitation and elevated residual volume (RV). No significant improvement is seen following bronchodilator administration, and resistance of the airways (R_{aw}) is markedly increased. The diffusing capacity (DLCO) is normal. In Figure 1, we see that the tracing of the expiratory flow at 50% of the vital capacity ($FEF_{50\%}$) is flat, both before and after bronchodilator, suggesting collapse or stenosis of the large intrathoracic airways.

Further Testing: A methacholine challenge test would establish the presence or absence of bronchial hyperactivity. If the methacholine challenge is negative and in light of the abnormal flow-volume pattern, tomography of the trachea and bronchoscopy are indicated.

Discussion

The absence of a bronchodilator response is somewhat surprising given the patient's asthma history and medication regimen. Failure to respond to bronchodilator administered in the pulmonary function laboratory can occur for several reasons. One common reason is that the patient took a bronchodilator prior to testing; however, our patient had withheld all medication for the appropriate time period. Another reason for failure to respond to inhaled bronchodilator in the laboratory may be that not enough of the medication reaches the lower airways. The medication may be trapped in the mouth or upper airway, or anatomic variants, such as enlarged tonsils or a narrowing of the trachea, may interfere. Physical characteristics of the medications (eg, particle size) or increased turbulent flow can reduce deposition. Another possibility is that the patient or technician administering the medication has difficulty coordinating the actuation of the inhaler with the subject's inspiration. However, a marked increase in our patient's heart rate following administration of the drug was documented, and, therefore, it is reasonable to conclude that enough active drug did reach the lower airways.[1]

During the methacholine challenge, a dose of 20 mg/mL was required to evoke the $PC_{20}FEV_1$ (a 20% fall in the FEV_1, or volume expelled during the first second of forced exhalation)—a normal response. The flow-volume loop obtained during the initial spirometry revealed an unusual expiratory flow pattern (Fig. 1). Not only is the $FEF_{50\%}$ completely flattened, but the $FEF_{50\%}$ before and after bronchodilator is actually lower than the $FEF_{75\%}$, albeit not by much. This characteristic pattern suggests collapse or stenosis of the large intrathoracic airways. Involvement of the large airways is also supported by the increase in R_{aw} seen in Table 1.

A computed tomogram confirmed focal narrowing of the tracheal lumen with tracheal wall thickening below the vocal cords, associated with asymmetry of the subglottic trachea. Bronchoscopy revealed that the cartilages were markedly deformed, and appeared fibrous. Due to possible cartilage instability, surgical consultation advised against biopsy of the airways. Overall, these findings suggest tracheomalacia.

Based on these findings, the patient was diagnosed with relapsing polychondritis, a disorder of unknown cause that affects hyaline and fibrocartilage of the respiratory tract, nose, ears, and joints. Pathologic findings include vacuolization of chondrocytes and destruction of cartilage with fibrous replacement. Involvement of the glottis, trachea, and major bronchi occurs in more than 50% of patients and is reported to be the primary cause of death.[2] The diagnosis of polychondritis is often made in conjunction with the appearance of bilateral auricular chondritis, which can give the ears a 'floppy' appearance.[3]

Pulmonary function tests often show varying degrees of expiratory obstruction, suggesting that the major airflow limitation is variable and is occurring in the intrathoracic airways. The abrupt decrease in flow on expiration near total lung capacity (TLC) is thought to represent dynamic intrathoracic airways compression caused either by airway collapse secondary to loss of cartilaginous supportive tissue from inflammation or by fixed narrowing from scar tissue.[4] Because elastic tissue is also affected by polychondritis, lung elastic recoil is often reduced, which reduces the driving force and results in decreased flow. Our patient demonstrated a relatively large difference in the volumes for slow vital capacity (SVC) and forced vital capacity (FVC). With the FVC maneuver, greater airways compression and collapse can occur, and, therefore, a smaller volume is often exhaled. The difference between the SVC and FVC which is easily obtained from spirometric results can be used as a surrogate index of airway collapse.[5]

Available evidence suggests that an autoimmune mechanism is involved in the pathogenesis of relapsing polychondritis. Successful treatment often includes immunosuppressive agents, such as intravenous methylprednisolone.[6] However, in more severe cases of tracheal collapse surgical intervention may be required, such as the placement of a silicone tracheal prosthesis.[7] Our patient did not require a tracheal prosthesis. On completion of her diagnostic workup at this institution, the prednisone was tapered. At present, she is being followed by the referring institution.

In summary, spirometry may provide a diagnosis of obstructive lung disease but cannot provide enough information to pinpoint a specific cause of obstruction. In this case, the spirogram showing a flattened expiratory flow suggesting intrathoracic collapse. Given the relatively young age of our patient and the absence of a positive smoking history, other diseases causing airway collapse (eg, polychondritis) needed to be considered. This case is a good example of how useful the simple flow-volume loop can be in suggesting a possible diagnosis in obstructive lung disease. Yet, it is surprising how infrequently this simple test is performed.

REFERENCES

1. McClellan M, Wanger J. PFT Corner #25—How much bronchodilator is enough? Respir Care 1987;32(5):355-357.
2. Krell WS, Staats BA, Hyatt RE. Pulmonary function in relapsing polychondritis. Am Rev Respir Dis 1986;133(6): 1120-1123.
3. McAdam LP, O'Hanlan MA, Bluestone R, Pearson CM. Relapsing polychondritis: prospective study of 23 patients and a review of the literature. Medicine 1976; 55(3):193-215.
4. Neilly JB, Winter JH, Stevenson RD. Progressive tracheobronchial polychondritis—need for early diagnosis. Thorax 1985;40 (1):78-79.
5. Chan ED, Irvin CG. The detection of collapsible airways contributing to airflow limitation. Chest 1995;107(3):856-859.
6. Lipnick RN, Fink CW. Acute airway obstruction in relapsing polychondritis: treatment with pulse methylprednisolone. J Rheumatol 1991;18(1):98-99.
7. Neville WE, Bolanowski JP, Kotia GG. Clinical experience with the silicone tracheal prosthesis. J Thorac Cardiovasc Surg 1990;99(4):604-613

Books, Films, Tapes, & Software

Listing and Reviews of Books and Other Media
Note to publishers: Send review copies of books, films, tapes, and software to RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593.

Clinical Assessment in Respiratory Care, Third Edition, by RL Wilkins, SJ Krider, and RL Sheldon. Softcover, 400 pages, 206 illustrations with index. St Louis: Mosby, 1995. $38.95.

With the increasing use of therapist-driven protocols and the proliferation of clinical practice guidelines, few subjects merit comprehensive texts of their own as much as does patient assessment. The clinician's ability to adequately evaluate the patient is essential to the successful implementation of protocols and to the application of assessment and monitoring sections of most guidelines. Appreciation of this increasing need for assessment skills is then likely to bring many students and current respiratory care practitioners to consider this text. The authors, from Loma Linda University, offer an appealing mix of perspectives: a respiratory therapy educator, a clinical department director, and a clinical professor of medicine. They state that the book is intended for students and practitioners in respiratory care; but students in nursing, medicine, and other health professions "will find this text helpful if they are to care for patients with cardiopulmonary disease."

The 18-chapter text is divided into 2 major sections: Fundamentals of Patient Assessment and Advanced Assessment Techniques. The time-honored backbones of pulmonary assessment (physical exam, arterial blood gas analysis, chest radiograph, and pulmonary function tests) appear in the first section; while the more specialized assessments (such as hemodynamic monitoring and evaluation of breathing during sleep) and assessments of special populations (eg, patients for home care and pulmonary rehabilitation) appear in the second. However, what makes one group of assessments more "advanced" than the other is not easily determined. The differentiation may stem more from where these assessments appear in the typical program curriculum than from anything else. In any case, both sections have been revised for the third edition with 4 new chapters. The new chapter entitled "Preparing for the Patient Encounter" and the one about vital signs are good expansions on the traditional history and physical examination processes. Two of the new chapters covering assessment of the home care patient and pulmonary rehabilitation appear, however, to lack the degree of detail one comes to expect from reading the other chapters in the book.

The 60-page companion *Quick Reference Guide* that comes with the text is intended as a supplement to, not a substitute for, the information presented in the parent text. As such, it is a pocket-size collection of normal values, definitions of terms used in respiratory care assessments, and concise reviews of common cardiorespiratory diseases. I found this pocket-reference supplement a supportive learning tool and an improvement over the many other clinical 'pocket guides' that have come and gone in our field. This guide is not only full of useful material, but it also follows the same format as the parent text to which the learner may easily refer for explanation and detail.

The chapters in the parent text are well illustrated with drawings that clarify the functions of physiology and pathophysiology that are being evaluated. The chapters, "Bedside Interpretations of Electrocardiogram Tracings" and "Invasively Monitored Hemodynamic Pressures," exhibit the good use of design and illustration. The book also contains helpful illustrations that explain how the technology of assessment works. From things as simple as a chest drainage system or a stopcock, to things as complex as a hemodynamic monitoring set up, drawings are used to explain the interface between patient and monitor and how the monitoring device performs its function.

The text is generally well written and understandable. I have used this edition of the text with 2 classes of baccalaureate respiratory care students and have already received several positive comments about clarity and usefulness of the text. Organization of the chapters is made clear by the inclusion of chapter outlines, overviews and references, and a liberal use of headings. The chapters are 'learner-friendly' with learning objectives at the beginning and review questions appearing at the end of each chapter. The objectives are specific and would be useful in determining how successful one's reading has been. An examination of the review questions reveals that many of them, like most of the assessments we use in formal education, are at the recall level.

To prepare the practitioner to perform the assessment process and to gain sufficient knowledge of the subject, the addition of case studies and practice evaluations throughout would improve the text. A reasonable improvement for a fourth edition would be to require, at least once in each chapter, that the reader analyze appropriate assessment data in case studies and draw appropriate general conclusions or make patient care decisions.

In summary, this reviewer finds the third edition of this work to be a satisfactory expansion of a sound text about an increasingly important subject. The addition of new chapters and the *Quick Reference Guide* are helpful. Most of the chapters are well written with considerable detail, supportive charts, graphs, and line drawings. With the increasing emphasis on patient assessment, the graduate practitioner is likely to find this text helpful to refresh and enlarge the evaluation skills that may have previously been underutilized in the work setting.

Phillip D Hoberty EdD RRT
Assistant Professor and
Director of Clinical Education
Respiratory Therapy Division
The Ohio State University
Columbus, Ohio

Bronkie, the Bronchiasaurus for the Super Nintendo Entertainment System,* 1991. $69.95.

Bronkie is a two-player, Super Nintendo action/adventure game. Bronkie and his friends, Trakie, Sam, and Kyla, live in San Saurian where meteors have struck, stirring up clouds of trouble. The object of the game is to help Bronkie and his friends collect the parts to a wind machine that will rid their world of asthma triggers such as dust, cigarette smoke, smoke, allergens, and cold germs.

During the game, the player must help Bronkie and his friends collect inhalers to keep them well and to replenish their health. Each player has a peak flow meter at the beginning of the game. (The player has to push a button on the control pad to bring up the screen with the peak flow meter on it.) The peak flow meter shows how healthy the player is. Players must use their peak flow meters, take their medications, and follow their health-care providers' directions every day. If they do not, the San Saurian world slowly becomes a blank screen. Correct answers to questions related to asthma will help the player progress further into the game or collect machine parts.

The game also provides asthma tips. One of the tips given in the game is: If you start to have asthma early warning signs, you should tell your parent immediately. This is a great tip for a kid who would benefit from the help of a parent; but for a teenager or an adult who has dealt with asthma for a long time, it may not help. I think that some of the tips could really be helpful to 10, 11, or 12 year olds. But, I also think that the tips and questions could be too easy for some people who have had asthma for a long time.

I think that this game is a fun way for kids to learn about asthma just because it's a video game, and video games are interesting to most kids. But in comparison to the other Super Nintendo games I've been playing, the graphics and the sound in **Bronkie** are only fair.

Jared Knauf
The Colony High School
The Colony, Texas

Editor's Note: Respiratory care practitioners who are teaching their new patients about asthma might find it interesting that the game has endorsements from the American Academy of Pediatrics and the Asthma and Allergy Foundation of America.

---

*Available from Rayasystems™, 2570 West El Camino Real, Suite 309, Mountain View CA 94040, (415) 949-3933.

Understand.
Adapt.
Prosper!

AARC

42nd International Convention & Exhibition
November 3-6 • San Diego, California

Letters

Letters addressing topics of current interest or material in RESPIRATORY CARE will be considered for publication. The Editors may accept or decline a letter or edit without changing the author's views. The content of letters as published may simply reflect the author's opinion or interpretation of information—not standard practice or the Journal's recommendation. Authors of criticized material will have the opportunity to reply in print. No anonymous letters can be published. Type letter double-spaced, mark it "For Publication," and mail it to RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593.

An Approach to Patient Classification

In an editorial in the June issue of the Journal,[1] Mr Giordano expounds on how we as a profession should place our patients who are receiving aerosol therapy into one of two groups—Category A patients whose condition requires that a respiratory care practitioner (RCP) be present throughout their aerosol treatment and Category B patients who after appropriate instruction and assessment by an RCP can self-administer their aerosol. We are not sure that we as a profession should be as dogmatic as Giordano proposes.

We do believe that the salient points here are consultation, follow-up, and evaluation of the patient. If we can transition patients from aerosol treatments via small volume nebulizer to metered dose inhaler (MDI) facilitated by patient-driven protocol, then we should do so. A number of papers have established the equivalence or superiority of MDIs for medication administration.[2-4]

A quandary may develop when patients who are using compressor-nebulizers at home must enter the hospital. If the physician has determined that a patient benefits from conventional home therapy, are we questioning the physician's judgment if we change the patient to an MDI when he or she enters the acute care hospital? It is this patient whom we believe should be considered for self-administration—but only within carefully formulated guidelines. By no means should we relinquish the patient altogether. If we stop seeing the patient, we fail to address the fact that the patient's condition can change and that ongoing monitoring and assessment are still necessary.

One of us (BB), one of the first per diem therapists at Holmes Regional Medical Center and an instructor at Brevard Community College, was the first to propose that the Medical Center use compressor-nebulizers in patients' rooms and allow patients who are normally on home aerosol therapy to self-administer their medication. The logistics and implementation of this program were worked out by the Respiratory Care Department's Manager (JF) with input from the Department's staff. The solution devised was this: The RCPs identify patients who are on home nebulizer therapy. The patients are assessed for proper frequency of medication administration and, if needed, additional treatment is suggested to stabilize the patient's condition. If it is determined that the patient requires only aerosol therapy, a compressor-nebulizer is placed at the bedside. The RCP is required to perform a full evaluation of that patient once a shift. During that assessment, the RCP remains with the patient for the duration of the treatment. Based on the shift-to-shift assessment made by the RCP, a decision is made to advance the patient to self-administration procedures. When it is time for the next treatment—scheduled or on as needed, prn, request—a self-administered treatment is arranged. The RCP goes to the patient's room, fills the prescribed medication into the nebulizer cup, and, following a brief visual assessment that assures that the patient is stable and that his or her condition has not changed markedly, leaves the room. The documentation for self-administered therapy reads like this: "Nebulizer filled with medication (name and dose) for self-administration." This requires only a few minutes, and the time saved in each of the subsequent self-administered treatments allows the RCP to spend more time with the patient whose condition requires that the RCP remain throughout the treatment—Giordano's Category A patient.

We emphasize that patient education is an important part of this process, and reinforcement and instruction are provided throughout the full assessment. We believe that this plan encourages the partnership between patient and RCP to maximize the quality of care. In health care today, we must do more with less but we also must not abandon our patients. We are convinced that the future of respiratory care rests on the RCP's ability to assess patients and to determine their respiratory needs. We must come up with creative solutions that can optimize our use of time and allow us to be flexible enough to meet patient needs.

Bruce Brown BS RRT
Director
Clinical Respiratory Care Program
Brevard Community College
Cocoa, Florida

Jeff Fraser RRT
Manager
Respiratory Care Department
Holmes Regional Medical Center
Melbourne, Florida

REFERENCES

1. Giordano SP. What we say versus what we do. Respir Care 1996;41(6):504-505.
2. Bowton DL, Goldsmith WM, Haponik EL. Substitution of metered dose inhalers for hand held nebulizers. Success and cost savings in a large, acute-care hospital. Chest 1993;101(2):305-308.
3. Hess D. Aerosol therapy. Respir Care Clin North Am 1995;1:235-263.
4. Zainudin BMZ, Biddiscombe M, Tolfree SEJ, Short M, Spiro SG. Comparison of bronchodilator responses and deposition patterns of salbutamol inhaled from a pressurized metered dose inhaler, as a dry powder, and as a nebulized solution. Thorax 1990;45(6):469-473.

Mr Giordano responds:

I can see from your letter that we are 'on the same page' with regard to appropriate utilization of respiratory care services and respiratory care practitioners. You correctly point out in your letter that "the salient point here is consultation, follow-up, and evaluation of the patient receiving therapy." I would rather see qualified respiratory care practitioners (RCPs) perform these functions than unqualified substitutes.

We all agree that RCPs should be involved with all patients who are receiving respiratory care clinical interventions. I have pointed out a way to do that while recognizing that not all patients require the same commitment of RCP time—given the ability of some patients to self administer. In my editorial, I did not advocate abandoning patients. As you may recall, I identified among other things the role of the RCP with regard to patients who can self-administer and described the RCP's role as "The respiratory care practitioner monitors the patient's self-treatment, offers tips regarding technique, and, of course, performs daily assessments of the patient's condition and

the appropriateness of the respiratory care order." If the foregoing statement has somehow been confused with "abandoning" the patient, then please accept my attempt to clarify. I believe that if we do not undertake the development of programs to 'downshift' patients, we will lose control of these patients because the responsibility will be taken from us by top decision makers.

In your letter, you make reference to transitioning patients to metered-dose inhalers (MDIs) from small volume nebulizers. Nowhere in my editorial did I advance that idea. I believe that establishing a program that allows classification of patients according to their need for the services of the RCP is a solid step towards rendering appropriate care of optimal quality while keeping an eye on costs. Such an approach should not be limited to one particular type of therapy. What should drive the decision regarding a patient classification system in this instance is the patient's ability—or lack thereof—to self-administer effectively, based on assessment performed by an RCP.

I was delighted to learn from your letter that you have set up a program that recognizes the differences among respiratory care patients. I hope that you will collect data related to the program and publish that data so that others can profit from your experiences.

Sam P Giordano MBA RRT
Executive Director
American Association for Respiratory Care
Dallas, Texas

42nd International Convention & Exhibition
SAN DIEGO
November 3-6, 1996, Sunday-Wednesday

RETROSPECTROSCOPE

Publisher's Dawdle: An Incurable Disease?

Like most people who complain about the weather, most scientists complain about long delays in publication, but few if any do anything about it. Roland and Kirkpatrick (1) divided into eight components the period between authors' hypotheses (conception of the idea) and date of publication of their manuscripts and determined the time required for each component. For papers dealing with laboratory or clinical investigation, the total time was about four years. The time for review and decision-making by the editors of journals was a little more than 1 1/2 months, for revision by authors about 3 months, and for the mechanics of publication (after final acceptance of a manuscript) about 5 1/2 months; the total time for "getting it published," once the manuscript was finished, was thus about 10 months.

It's the figure of 5 1/2 months, the mechanics of publishing, that puzzles me. Some editors take the position that since the process of research and writing a manuscript may take a year or two, why fuss about speeding up the mechanical process of publication by 4 to 5 months? But slow publication is an anachronism in the modern era of electronics and computers which have revolutionized not only the speed of making scientific measurements but also the process of printing and reproduction. A Sunday newspaper, one almost too heavy to lift, can be put together once a week. In some of its sections, it includes news that is only a few hours old and readers would scream if the "news" was any older. But a scientific journal, about 1/3 the weight, takes 5 1/2 months for the purely mechanical tasks of copy editing, typesetting, proof reading, printing, and binding!

It has not always been so. If we look way back through the Retrospectroscope into the seventeenth century, we see that the editor of *Philosophical Transactions of the Royal Society* stopped the press to publish Robert Hooke's experiments (2) proving that motion of the lungs and thorax was not essential to life as long as fresh air reached the alveoli; he accomplished alveolar ventilation without motion of the thorax or lungs by pricking many spots on the outer surface of the lungs with a sharp, pointed knife and then blowing a steady flow of air through the trachea, bronchioles, and alveoli, out to the surrounding air. The editor's explanation is reproduced in figure 1; in it, he notes that the experiment had been repeated as a demonstration before a public assembly, and that this obviously constituted satisfactory editorial review. The reception must have warranted instant publication and, since the industrial, electrical, and electronic revolutions and the U. S. Postal Service had not yet been invented, instant publication seems to have been a fairly simple matter.

An Account
*Of an Experiment made by M.*Hook, *of Preſerving Animals alive by Blowing through their Lungs with Bellows.*

This Noble Experiment came not to the Publiſher's *hands, till all the preceding Particulars were already ſent to the Preſs, and almoſt all Printed off, (for which cauſe alſo it could not be mentioned among the* Contents:) *And it might have been reſerved for the next opportunity, had not the conſiderableneſs thereof been a motive to haſten its Publication. It ſhall be here annexed in the Ingenious* Author *his own words, as he preſented it to the* Royal Society, Octob. 24. 1667. *the Experiment it ſelf having been* both *repeated (after a former ſucceſsful trial of it, made by the ſame hand a good while ago)* and *improved the week before, at their* publick Aſſembly. *The Relation it ſelf followes;*

Figure 1

In the nineteenth century, the Retrospectroscope shows that Roentgen's experiments on X-rays were published within weeks of the completed observations (3). No one knows when Roentgen completed the experiments reported in his December 28, 1895 paper but he presumably made his first observation on November 8, 1895. He then proceeded, to be sure that these were indeed previously unknown rays, to study the effect of various metals of different thicknesses on the passage of X-rays and to determine whether the rays could be refracted, reflected, condensed, or deflected by strong magnetic fields. These experiments, and his writing a ten-page paper, must have taken him until mid-December. Whether the *Sitzungsberichte* for December 1895 was actually published in late December or the first week in January 1896, we do not know. But, for certain, Roentgen had reprints (or preprints) before January 1, and, for certain, a complete English translation appeared in *Nature* in its January 23, 1896 issue, crossed the Atlantic, and was reprinted in *Science* in its February 14

Reprinted with permission of the American Lung Association, from Am Rev Respir Dis 1977;115:131-134.

issue. Incidentally, none of the three editors bothered to comment on the speed of publication in German, English, or American journals.

The world's record, however, was probably made in that same year by Thomas Cullen in Baltimore for his paper, "A rapid method of making permanent specimens from frozen sections by the use of formalin," which appeared in the *Johns Hopkins Hospital Bulletin* in 1895 (vol. 6, p. 67). According to Cullen, as reported by Harvey (4):

> I tested the formalin method I had worked out on every sort of tissue and in every way I could think of. Then I went upstairs showing one of my sections to Dr. Welch and told him how I had hardened it and how long it had taken me. He looked at it and listened. Then he handed me a piece of tissue ... "Take this and prepare it your way," he said. "If you make me a satisfactory specimen, I will be convinced." I took the tissue and made a specimen and brought it back. Popsy looked at it, looked at his watch and said, "Publish it." So I did. I wrote up the method and took my paper to Dr. Hurd, who was then editor of *The Johns Hopkins Hospital Bulletin*, the same night, but it was nearly too late. Dr. Hurd said he was sorry but the last copy for the next issue of the *Bulletin* had gone to the printer and mine would have to wait a month. I was going away on that comment, but he called me back and asked me how much space I would need to describe my hardening method. I said half a page, and he said "go ahead and write it then." "It's written," I said, and gave it to him and it was in print in the *Bulletin* two days later.

At the beginning of this century, Dr. L. L. Hill of Birmingham, Alabama, performed the first successful operation on a heart in America: he sutured a stab wound in the heart of a 13-year-old boy.* Dr. Hill operated on September 14, 1902 and kept his patient in the hospital until at least early October. His report related not only this experience but included a scholarly review of the world's literature on wounds of the heart and their management. He had previously reported on 17 such cases but brought his list up to 39 reports that had been published in at least four foreign language journals. This (while still attending to a busy practice) must have taken him into November. Yet his article was published in an American medical journal on November 29, 1902 (5).

In 1922, Schofield's discovery that hemorrhagic disease in cattle was caused by their munching on moldy sweet clover (and that plasma prothrombin was greatly decreased in these diseased animals) was published so quickly that Schofield felt compelled to write an apology as his final paragraph (6):

> This paper has been written very hurriedly as the editor was insistent that it appear in this issue. I therefore ask the readers to be lenient in their criticism, not of the contents, but of the arrangement of the material presented.

Looking backward only 6 to 7 years, on January 30, 1970, *Science* published its "Moon Issue" (7). It brought together in one issue 144 scientific articles dealing with the scientific aspects of the first scientific exploration of the surface of the moon. The total time from receipt of the authors' manuscripts to mailing the completed journal was 24 days! *Science* magazine was not shy in reporting its achievement in rapid publication of scientific reports: it presented in tabular form each step in the process and how long it took (table 1) (8).

Table 1. Dates of Start and Finish of Each Step in the Publication of the Apollo 11 Lunar Science Conference Issue of *Science*

Step	Dates
Receipt of manuscripts from authors	4-7 January
Reviewing of manuscripts	4-8 January
Authors' responses to reviews	5-8 January
Style editing and marking for printer	5-12 January
Redrafting and relettering illustrations	5-12 January
Authors' responses to style editing	5-23 January
Preparation of engravings	8-22 January
Typesetting	9-19 January
Proofreading of galley proofs	10-19 January
Paste-up of page dummies	13-20 January
Correction of galleys and makeup of pages	13-21 January
Proofreading of page proofs	17-24 January
Correction of pages	20-26 January
Proofreading of revised page proofs	21-27 January
Printing	23-28 January
Binding	28-30 January
Mailing	28-31 January

This table is wonderfully informative: first, it shows each step in the process between receiving manuscripts and mailing them, professionally edited and printed in a journal, to 150,000 subscribers; and second, it shows how little time is really needed when someone makes up his or her mind to accord scientific articles the treatment regularly given by the daily press to murder, rape, war, and football games.

Once it demonstrated that it could be done, did *Science* continue to publish at this fast pace? Except for the staff of *Science* and individual contributors who keep logs, no one knows; I would guess that for some individual articles or letters it does publish quickly but that for most it does not.

Turning the Retrospectroscope into my own closed files, I learned that in late 1965, the Publications Committee of the American Heart Association asked me to be editor of *Circulation Research* for a 5-year term. I checked the time required for publication of accepted articles and found that it was about

*Dr. Hill is also remembered as the father of Senator Lister Hill, long a supporter of the National Institutes of Health and the National Library of Medicine.

6 months. I then asked the editor of *Proceedings of the National Academy of Sciences* for her publication schedule and learned that it was *6 weeks*. So my answer was easy: "If *Circulation Research* can match the publication schedule of PNAS, I'd like to take the job." The Publications Committee arranged a meeting for me with the publisher, printer, and engraver, at which I asked, "Can you put the printed journal in the mail 6 weeks after you get the last manuscript for it?" The answer came back immediately—"Sure." Taken by surprise, I asked, "Then why do you now take 6 months?" The answer was even more amazing—"No one ever asked us to do it in 6 weeks." "Will it cost more?" "No." So I signed an agreement with the American Heart Association; paragraph 12 stated:

> It is understood that the Editor is vitally concerned with reducing the time between acceptance of a manuscript and its publication. The Association agrees to cooperate with the Editor to reduce this span and to pay for reasonable editorial staff required to meet the Editor's goal. It is further understood that if the Association is unable to meet the Editor's requirements on this point the Editor's term will conclude as of the December, 1967 issue upon notice given by him to the Publications Committee no later than January 1, 1967.

I never gave notice to the Committee because for the next 5 years, with minor exceptions, all articles accepted by the first of one month were in a bound journal in the mails on the 15th of the next month.†

Speedy publication has many advantages. Obviously, it speeds proper announcements of new advances of importance to physicians (and to their patients) and to other scientists; it speeds publication of accurate accounts of other observations, less dramatic in themselves, but vitally important to the work of other scientists, possibly in unrelated fields; it could put an end to first announcement of "breakthroughs" in the "throw-away" medical journals, newspapers, and newsweeklies; and it might improve the quality of science by rechanneling scientific reports back into carefully edited journals and away from "quickie" journals that photograph and publish unreviewed, unrevised, unedited typewritten reports.

How are some heart and lung journals doing in 1976? Here are some figures for 6 journals during a 3-month period (table 2).

In their 1975 article, Roland and Kirkpatrick (1) divided the total time lapse between conception of the idea and final publication into eight components: planning time, research time, writing time, unexplained author delays, time for institutional editing, time for journal handling, revision time, and time for publication. I've never believed that one should hurry poorly conceived and badly done research through the planning and working stage and rush it off to an editor. I *do* believe that well-done work, accepted by critical reviewers, deserves as rapid publication as the funny papers. A lot of patients could die in a 5 1/2 month period between acceptance of the first paper on penicillin or sulfanilamide and its publication. Isn't it time that we catch up with the 1667 schedule of the Royal Society?

Table 2. Time between Date of Acceptance of Manuscript and Date of Publication of Journal

Journal	No. of Articles	Average Lag* *(months)*
Journal of Clinical Investigations (concise articles)	2	2.0
American Review of Respiratory Disease	47	3.2
Circulation Research	57	3.9
Respiration Physiology	33	3.9
Journal of Clinical Investigation (full articles)	84	4.2
Circulation	68	4.4
Chest	32	5.3

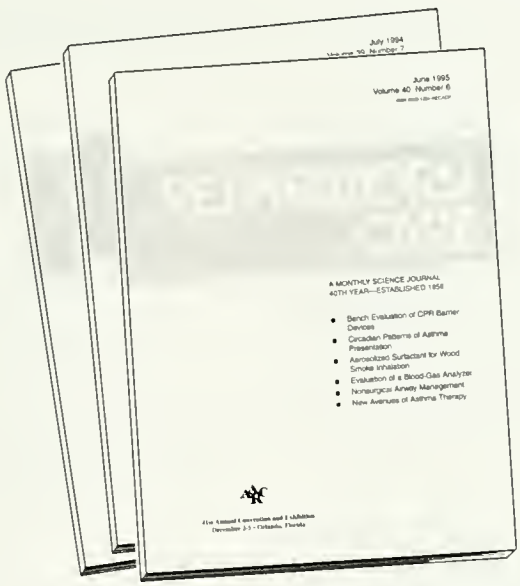
*These figures were calculated from the following data in each issue: Day #1 of the month printed on the journal's cover, and "date accepted," usually printed at the bottom of page 1 of each article in that issue. This calculation gives the *minimal* lag because (a) the official date of publication and mailing of a journal may be mid- or end-month and not day #1; (b) journals labeled October may actually be published later, even in the next month; and (c) no allowance is made for the weeks (?) that the journal is in the hands of the U.S. Postal "Service."

Julius H. Comroe, Jr.

†To keep everything honest, a "six-week" lag between accepting and publishing a manuscript in a monthly journal is six weeks only for those accepted near the monthly deadline; it's ten weeks for those that just missed the last deadline and so an average figure of eight weeks is about right. For a weekly publication, this range in lags would not apply.

REFERENCES

1. Roland, C.G., and Kirkpatrick, R. A.: Time lapse between hypothesis and publication in the medical sciences. N Engl J Med, 1975, 292, 1273-1276.
2. Hooke, R.: An account of an experiment made by M. Hook[e], of preserving animals alive by blowing through their lungs with bellows. Philos Trans R Soc Lond, 1667, 2, 539-540.
3. Röntgen, W. C.: Ueber eine neue Art von Strahlen, Sitzungsber Phys Med Gessel Würzburg, 1895, 134, 132-141.
4. Harvey, A. M.: The second professor of gynecology and the department of art as applied to medicine. Johns Hopkins Med J, 1975, 137, 224-234
5. Hill, L. L.: A report of a case of successful suturing of the heart, and table of thirty-seven other cases of suturing by different operators with various terminations, and the conclusions drawn. Med Rec, 1902, 61, 846-848.
6. Schofield, F. W.: A brief account of a disease in cattle simulating hemorrhagic septicaemia due to feeding sweet clover. Can Vet Rec, 1922, 3,74-78.
7. Science, 1970, 167, 415-794.
8. Ibid., p. 781.


June 1995
Volume 40 Number 6
A MONTHLY SCIENCE JOURNAL
40TH YEAR—ESTABLISHED 1956
Bench Evaluation of CPR Barrier Devices
Circadian Patterns of Asthma Presentation
Aerosolized Surfactant for Wood Smoke Inhalation
Evaluation of a Blood-Gas Analyzer
Nonsurgical Airway Management
New Avenues of Asthma Therapy

CRCE through the Journal–1996

We are delighted to bring you the seventh edition of ***CRCE through the Journal***, a program for AARC members to gain credit for continuing education by careful reading, thoughtful study, and test completion. The acceptance of these credits for the fulfillment of license-mandated continuing education is dictated solely by the licensure law of each individual state.

This year, we are indebted to the efforts of Crystal Dunlevy EdD RRT,* F Herbert Douce MS RRT, and Phillip D Hoberty EdD RRT, who authored the test. This 50-item multiple-choice examination is based on papers published in RESPIRATORY CARE from July 1995 through June 1996. The issue and page numbers of the paper on which a question is based are shown in brackets following the question. You are free to consult the cited paper as you complete the answer sheet. However, we encourage you to read the paper in its entirety before answering the questions. Then, choose the single most-correct answer, and carefully mark the answer sheet, ***which is located at the back of this issue following page 776***. Remember ***CRCE through the Journal*** is an honor system, and the benefits you derive are directly proportional to the effort you invest.

Mail your completed answer sheet by September 30, 1996. Answer sheets postmarked after September 30 will not be processed. The Answer Key for ***CRCE through the Journal*** will be published in the October issue of RESPIRATORY CARE. No scores will be available from the AARC until the 1996 CRCE Transcripts are mailed in early 1997.

---

* Dr Dunlevy is an Adjunct Faculty Member with Georgia State University—Atlanta, Georgia. When this test was written she was Associate Professor and Director of Clinical Education, Dr Hoberty is Assistant Professor, Respiratory Therapy Division, and Mr Douce is Assistant Professor and Program Director, School of Allied Medical Professions—The Ohio State University, Columbus, Ohio.

QUESTIONS:

Please follow the instructions on the previous page, and record your answers on the perforated form provided at the back of the Journal following page 776.

1. Betit et al observed that what circumstances may make inhaled nitric oxide (NO) unsafe for infants on mechanical ventilation?

   a. NO doses > 40 ppm with $F_{DO_2} > 0.95$
   b. NO administered with 5-mm ID tubing
   c. NO scavenged continuously with vacuum
   d. NO administered by continuous titration
   e. NO doses determined by gas analysis only

   [July 1995;40(7):706-715]

2. In the study by Haas et al, which of the following values were *significantly* higher when patient-determined flow, rather than preset flow, was allowed during assisted mechanical ventilation?

   a. $\dot{V}_{max}$ and P_{etCO_2}
   b. $\dot{V}_E$ and P_{es}
   c. Hemodynamic and metabolic data
   d. WOB_{pt} and respiratory drive
   e. $PEEP_i$ and $P_{0.1}$

   [July 1995;40(7):716-721]

3. From the study by Gilmore et al, which is a true statement about airway occlusion pressure ($P_{0.1}$)?

   a. In normal subjects, it has no relationship to other measurements of central neuromuscular output.
   b. It is measured during the first 100 milliseconds of inspiration at FRC.
   c. It is not useful as a predictor of success in weaning from mechanical ventilation.
   d. It is measured when the airway is open to atmospheric pressure.
   e. It is an invasive assessment.

   [July 1995;40(7):722-727]

4. According to the study by Russell and Graybeal, covering disposable oximeter sensors with a protective laminate resulted in:

   a. false high S_{pO_2} measurements.
   b. false low S_{pO_2} measurements.
   c. S_{pO_2} measurements that were not clinically different from single-use sensors.
   d. diminished response times that were judged to be clinically important.
   e. decomposition of the sensor.

   [July 1995;40(7):728-733]

5. Yuan, Jun, and Min demonstrated that pulse-dose oxygen therapy:

   a. was not cost-effective compared to continuous-flow oxygen delivery.
   b. used approximately one third the amount of oxygen as continuous-flow oxygen therapy.
   c. used about the same amount of oxygen as continuous-flow oxygen therapy.
   d. used approximately one third more oxygen than continuous-flow oxygen therapy.
   e. is more efficient than continuous-flow oxygen therapy when delivered via liquid systems only.

   [August 1995;40(8):811-814]

6. In Limauro and colleagues' study of inhaled bronchodilator response, which of the following **was not** a finding?

   a. Nebulized albuterol produced significant improvement in spirometry on Day 1.
   b. Nebulized albuterol produced significant reduction in breathlessness ratings on Day 1.
   c. There was good reproducibility of data between Days 1 and 2.
   d. Changes in breathlessness ratings did not correlate with changes in spirometry values.
   e. Spirometry improved even in the subgroup of patients randomized to inhale normal saline.

   [August 1995;40(8):815-819]

7. Liffman et al suggest that what quality control material can be used to adequately assess imprecision of blood-gas, electrolyte, and CO-oximeters instruments?

   a. ABC™ Control
   b. Qualidata™ 623
   c. Blood G.A.S. Control™
   d. Tonometered EQUIL™ Plus
   e. Fluorocarbon emulsion controls

   [August 1995;40(8):820-831]

8. According to Medin and Ognibene, **all but which** of the following will minimize occupational risk associated with treatment of the patient suffering from AIDS?

   a. Universal Precautions should be used only in treating patients who are at risk for the human immunodeficiency virus.
   b. Masks should be worn to minimize risk of tuberculosis transmission.
   c. Particulate respirators should be worn during aerosol administration of pentamidine.
   d. RCPs who are pregnant should not be exposed to aerosolized pentamidine.
   e. Disposable mouthpieces and tubing should be used whenever possible.

   [August 1995;40(8):832-854]

9. Criner and Isaac report that **all but which** of the following contribute to psychological problems that may occur in the ICU patient?

   a. sleep deprivation
   b. sensory deprivation
   c. poor baseline psychologic function
   d. less severe illness
   e. adverse effect of medication(s)

   [August 1995;40(8):855-865]

10. Which of the following agents is specific to the pulmonary vasculature, according to Mathewson?

    a. nitric oxide
    b. calcium - channel blockers
    c. adenosine
    d. anticoagulants
    e. Prostacyclin

    [August 1995;40(8):871-875]

11. From the paper by Pierson, which **is not** a recommended improvement in current mechanical ventilator design and function?

    a. increased versatility, adaptability, and responsiveness of ventilators
    b. ability to generate higher peak pressures and volumes
    c. ability of ventilators to recognize and monitor auto-PEEP
    d. ability of ventilators to detect failure to meet patient's flow and volume needs
    e. standardization of ventilator alarms among models and manufacturers

    [September 1995;40(9):933-941]

12. From the paper by MacIntyre, which is the best descriptor of clinical outcome assessment in evaluating innovations in mechanical ventilation?

    a. complex and expensive study, often involving careful randomized clinical trials
    b. inexpensive and innovation-specific evaluation of ventilator performance
    c. measurements of specific physiologic variables linked to anticipated mechanisms of benefit or risk
    d. evaluation in which real clinical efficacy is inferred rather than tested
    e. evaluation of operational variables such as flow rate or response time

    [September 1995;40(9):968-970]

13. From the paper by Tobin et al, which **is not** a study design issue in using physiologic end points to evaluate innovations in mechanical ventilation?

a. the selection of the control-comparison state
b. control of other physiologic variables
c. the timing of measurements
d. the verification of physiologic outcomes by long-term outcomes
e. the number of intermediate end points
[September 1995;40(9):971-974]

14. Dellinger points out that in choosing which long-term end point must you consider that there is a probability that no statistically significant benefit will be found when one does exist due to failure to enroll a sufficiently large number of patients?

a. morbidity
b. surrogates
c. indices
d. mortality
e. composites
[September 1995;40(9):975-979]

15. **All but which** of the following is true of the APACHE II and/or SAPS II scoring systems?

a. Both are used to estimate probability of hospital mortality for ICU patients.
b. APACHE II uses a greater number of variables than does SAPS II to estimate mortality.
c. APACHE II is a better predictor of mortality than SAPS II, according to Del Bufalo and associates.
d. APACHE II and SAPS II use different combinations of variables to predict mortality.
e. APACHE II was developed before SAPS II.
[October 1995;40(10):1042-1047]

16. Chatila et al observed that if an evident outlier had not been excluded from analysis in their study, endotracheal suctioning would have resulted in a significant change in which variable?

a. respiratory system compliance (C_{rs})
b. airway resistance (R_{aw})
c. static resistance to breathing
d. pause (plateau) pressure
e. systemic vascular resistance
[October 1995;40(10):1048-1051]

17. Shaw and Prewitt advocate the use of which of the following to rank prospective respiratory therapy program candidates?

a. 3-semester respiratory care course GPA regression
b. CRTT self-assessment examination regression
c. preprofessional GPA
d. a and b
e. exit GPA regression
[October 1995;40(10):1052-1062]

18. Noblett et al report which outcome when trained registered respiratory therapists (RRT) provide neonatal intubation in a community hospital setting?

a. There is role conflict with pediatricians.
b. The incidence of esophageal intubation is 10%.
c. There is an alarming incidence of complications .
d. Most intubations are accomplished with 1 attempt.
e. Few tubes must be reinserted by an anesthesiologist.
[October 1995;40(10):1063-1067]

19. On the basis of their findings, Mishoe and colleagues recommend that to minimize risk of hearing loss, what type of humidification equipment should the RCP use for an infant receiving supplemental oxygen in a hood?

a. SPAG-2
b. simple humidifier
c. heated humidifier
d. heat/moisture exchanging humidifier
e. heated nebulizer with low water level
[November 1995;40(11)1120-1124]

20. Which of the following **is not** one of the conclusions reported in Komara and Stoller's study of postoperative oxygen therapy protocol?

a. RCPs are more likely than other health-care providers to implement practice guidelines.
b. Closer attention should be given to the assessment of preoperative oxygenation in order to define postoperative therapeutic end points.
c. Most patients were immediately taken off of supplemental oxygen when room air S_{pO_2} reached 92%.
d. Physicians often utilize a wide range of S_{pO_2} criteria when assessing oxygenation.
e. Patients with a preoperative recorded S_{pO_2} often had a greater S_{pO_2} stop criterion.
[November 1995;40(11):1125-1129]

21. Kollef and Silver suggest which statement is true concerning ventilator-associated pneumonia (VAP)?

a. VAP refers to a pneumonia that develops in a mechanically ventilated patient later than 48 hours after intubation.
b. VAP is associated with the single risk factor of prophylactic antibiotic therapy.
c. When patient demographics and underlying severity of illness is controlled for, VAP is eliminated as an independent predictor of hospital mortality.
d. Bronchoscopic sampling of the lower airways is a relatively inaccurate method of diagnosing VAP.
e. Direct aspiration is a relatively uncommon mechanism for development of VAP.
[November 1995;40(11):1130-1140]

22. Branson and Davis found which to be a true statement about the performance of the 5 ventilators in this study?

a. The ICU ventilators demonstrated a significantly higher WOB_I during spontaneous breathing than did the home care ventilators.
b. Statistically significant difference in the WOB_I between 2 ventilators in PSV may or may not be clinically important.
c. The application of PEEP equally affected the performance of all the ventilators tested.
d. The WOB during IMV and PSV was measured for all the ventilators in this study.
e. There were no statistical significant differences in the WOB_I among the ICU ventilators.
[December 1995;40(12):1270-1278]

23. Documented advantages of nasal long-term endotracheal intubation over oral long-term endotracheal intubation include **all but which** of the following?

a. lack of bite block requirement
b. less incidence of laryngeal damage
c. improved stability
d. improved oral hygiene
e. less incidence of sinusitis
[December 1995;40(12):1279-1286]

24. Chaska et al suggest that obstructive sleep apnea is most commonly seen in:

a. men who exhibit loud, chronic snoring.
b. men with a neck circumference of 16 inches.
c. women with unexplained pulmonary hypertension.
d. women more than 40 years old who exhibit changes in personality.
e. men or women who are 115% of their ideal body weight.
[December 1995;40(12)1287-1294]

25. According to Cordero et al, what is the significance of serial tracheal cultures positive for *Ureaplasma urealyticum* in mechanically ventilated infants?

a. correlated with infant mortality
b. associated with the severity of BPD
c. common among small, premature infants
d. directly related to the development of PPHNB
e. usually an antimicrobial resistant organism
[January 1996;41(1):22-29]

26. Hagarty and associates' study of the use of pulse oximetry to determine oxygen prescriptions in COPD patients suggests that:

    a. oxygen administration during exercise does not improve exercise tolerance.
    b. S_{pO_2} measured during a 5-minute corridor walk can be used to predict oxygen flow in COPD patients in nasal cannulas.
    c. S_{pO_2} measured at rest in COPD patients on nasal cannulas did not differ significantly from S_{pO_2} measured during a 5-minute walk.
    d. COPD patients should be prescribed oxygen via nasal cannula at 1-3 L/min.
    e. oxygen prescriptions for COPD patients should be titrated to $S_{pO_2} \geq 95\%$.

    [January 1996;41(1):30-36]

27. According to the survey by Kasper et al, what is the current clinical tracheostomy practice in an urban university teaching hospital?

    a. Most tracheostomy patients receive respiratory care.
    b. Only a few patients are admitted with a tracheostomy.
    c. Spinal cord injury is a common reason for tracheostomy.
    d. Prolonged ventilation is a rare reason for tracheostomy.
    e. Tracheostomy is most often performed by general surgeons.

    [January 1996;41(1):37-42]

28. Miyao et al quote the current international standard for airway humidification of bypassed airways as

    I. absolute humidity of > 30 mg H_2O/L
    II. relative humidity of > 85%
    III. temperature = 35-37° C

    a. I only
    b. II only
    c. I and III
    d. II and III
    e. I, II, and III

    [January 1996;41(1):43-49]

29. Approximately what percentage of drowning victims vomit either during drowning or during resuscitation attempts?

    a. 10%
    b. 20%
    c. 30%
    d. 40%
    e. 50%

    [January 1996;41(1):50-57]

30. Volsko et al reported that when an inexpensive commercial standard is used to verify the accuracy and precision of pulse oximeters, the results compare with manufacturer's specifications in which way?

    a. Precision was less than specifications.
    b. Error was always within specifications.
    c. Bias was significantly greater than specifications.
    d. Accuracy was within ± 4% of specifications.
    e. Inaccuracy intervals were approximately 4%.

    [February 1996;41(2):100-104]

31. From Ravenscraft's paper, which of the following is true concerning the use of tracheal gas insufflation (TGI) as an adjunct to conventional mechanical ventilation?

    a. Of all forms of phasic TGI, partial inspiratory bypass is the most effective.
    b. The addition of TGI to conventional mechanical ventilation makes pressure and volume monitoring easier to accomplish.
    c. If continuous flow TGI is combined with pressure-controlled ventilation, the danger of overpressurization is eliminated.
    d. Auto-PEEP and plateau pressure determinations are more difficult to make during continuous flow TGI.
    e. $P_{et\,CO_2}$ appears to be the best monitoring tool for continuous flow TGI.

    [February 1996;41(2):105-111]

32. From the paper by Trant et al, which statement is correct concerning the regulation of myocardial contractility and function?

    a. In ventricular tachycardia, cardiac filling time increases along with cardiac output and myocardial oxygen consumption.
    b. Stroke volume is controlled by three factors—preload, afterload, and contractility.
    c. An increase in venous return generally results in an increase in ventricular stretch and a decrease in preload and cardiac output.
    d. In most ICU situations, the left ventricular systolic pressure is used to estimate end-diastolic ventricular volume.
    e. As long as preload and heart rate do not change, a decrease in afterload causes a decrease in stroke volume and cardiac output.

    [February 1996;41(2):113-122]

33. **All but which** of the following is true of oxygen delivery?

    a. When oxygen delivery is inadequate to meet the demand of the tissues, anaerobic metabolism occurs.
    b. As cardiac output decreases, oxygen delivery decreases.
    c. Positive pressure ventilation increases oxygen delivery.
    d. Decreased right ventricular preload in patients with right ventricular dysfunction may cause decreased oxygen delivery.
    e. Reduction in gas exchange decreases oxygen delivery.

    [February 1996;41(2):123-129]

34. According to Boix and colleagues, which type(s) of ventilatory support resulted in improvement in the alveolar ventilation of COPD patients?

    a. NIPPV
    b. EHFOV
    c. CPAP
    d. a and b
    e. Bilevel CPAP

    [March 1996;41(3):187-190]

35. El-Khatib and Rosalowski suggest that when a metabolic cart is not available, what combination of variables can be used to estimate the energy expenditure for adolescent boys on mechanical ventilation?

    a. age, F_{IO_2}, $\dot{V}_E$
    b. age, height, weight
    c. F_{IO_2}, weight
    d. height, pulse, weight
    e. $\dot{V}_E$, weight, pulse

    [March 1996;41(3):191-196]

36. Which conclusion is supported by the results of the study by Gerber et al?

    a. Use of the disposable cover would result in little potential cost savings for hospitals.
    b. The disposable probe cover should not significantly alter accuracy of the measured S_{pO_2}.
    c. The use of the probe cover is likely to encourage probe damage.
    d. The findings of the study may be true only for patients who have a relatively low S_{pO_2}.
    e. The difference in S_{pO_2} as measured by sheathed and unsheathed probes should be no more than 1%.

    [March 1996;41(3):197-201]

37. According to their survey on the prevalence of cigarette smoking, Wilson and Cohn reported **all but which** of the following?

    a. Less than one half of RCPs surveyed are smokers.
    b. The majority of RCPs surveyed do not routinely ask family members about their smoking habits.
    c. Most RCPs counsel parents about secondhand smoke.
    d. The majority of respiratory care departments do not provide information to family members about secondhand smoke.
    e. Very few hospitals surveyed have smoking cessation programs.

    [March 1996;41(3):202-205]

38. The Centers for Disease Control reported that increased risk for HIV infection following percutaneous exposures to HIV-infected blood was associated with **all but which** of the following?

    a. device visibly contaminated with the patient's blood
    b. procedure that involved a needle placed directly in a vein/artery
    c. deep puncture injury
    d. exposure to blood from source patients with terminal illness
    e. avoidance of zidovudine following exposure

    [March 1996;41(3):206-208]

39. Purely antihistaminic drugs:

    a. are effective in the treatment of asthma.
    b. are not effective in the treatment of asthma.
    c. are effective in the prevention of asthma.
    d. are effective in treating the late-phase inflammatory response in asthma.
    e. produce a synergistic effect when prescribed with a bronchodilator.

    [March 1996;41(3):212-214]

40. Peruzzi explains that when optimal PEEP is applied to a patient with noncardiogenic pulmonary edema, the mechanism thought to be responsible for improving oxygenation is:

    a. decreased venous return.
    b. decreased cardiac output.
    c. increased alveolar volume.
    d. redistribution of lung water.
    e. increased plasma renin activity.

    [April 1996;41(4):273-284]

41. From the paper by Branson and MacIntyre, which statement is true concerning volume-controlled ventilation (VCV)?

    a. Constant volume delivery remains the compelling factor in the selection of VCV.
    b. In VCV, "flow starvation" is likely to lead to patient-ventilator dyssynchrony and a reduction in the WOB.
    c. Excessive airways pressures that can cause barotrauma and volutrauma do not occur in VCV.
    d. In VCV, volume serves as the usual phase variable for limit and cycle of the mandatory breath.
    e. In most reported studies of dual control ventilation, VCV resulted in less WOB than did PCV or VAPSV.

    [April 1996;41(4):294-305]

42. Which of the following treatments for severe respiratory failure described in Wilson's paper also provides cardiac support?

    a. IVOX
    b. $ECCOR_2$
    c. V-V bypass
    d. V-A bypass
    e. arterial-arterial ECMO

    [April 1996;41(4):306-317]

43. According to East and Morris, what is true about decision support systems (DSS)?

    a. Specific executable protocols contain knowledge-based instructions that are complete, clear and concise.
    b. Clinical practice guidelines are the most appropriate DSS for making specific decisions concerning quality of care or reducing costs.
    c. DSS are not likely to result in computer applications.
    d. DSS led to standardizing treatment as well as standardizing clinician response.
    e. All DSS function as closed-loop control systems.

    [April 1996;41(4):327-340]

44. Which form of high-frequency ventilation provides active inspiration and expiration and a fixed I:E of 1:1 according to Herridge and Slutsky?

a. HFJV
b. HFOV
c. HFFIV
d. HFPPV
e. $HFCO_2RV$

[May 1996;41(5):385-396]

45. Which natural exogenous surfactant preparation is FDA-approved for neonates and is usually administered as a bolus of 3-5 mL/kg while interrupting CMV, according to Haas and Weg?

a. ALEC
b. CLSE
c. Curosurf™
d. Exosurf™
e. Survanta™

[May 1996;41(5):397-411]

46. What liquid is used to provide partial liquid ventilation at atmospheric pressure?

a. H_2O_2
b. NS, 0.9% NaCl
c. perfluorocarbon
d. phosphatidylglycerol
e. dipalmitoylphosphatidycholine

[May 1996;41(5):416-423]

47. Hess et al found that which one of the following **has not been shown** as the result of nitric oxide (NO) inhalation?

a. clinically important increase in bleeding times for patients with ARDS
b. pulmonary edema in patients with left ventricular dysfunction
c. pulmonary hypertension as a rebound effect when NO was withdrawn
d. development of NO_2 in breathing systems in the presence of high F_{IO_2}
e. unpredictable change in P_{aO_2}/F_{IO_2} in patients with ARDS.

[May 1996;41(5):424-446]

48. The results of the study by Marik reasonably supports what conclusion?

a. Consider the leak test as an invalid predictor of post-extubation stridor.
b. Expect all patients who fail to show a leak in the leak test to develop stridor.
c. Expect no postextubation stridor in patients who show a leak during the leak test.
d. Consider nasal intubation to be superior to oral intubation in the prevention of postextubation stridor.
e. Endotracheal tube size should be limited to < 8.0 mm ID.

[June 1996;41(6):509-511]

49. Bhatt and colleagues suggest that which is an advantage of tracheal pressure-triggering CPAP over conventional within-ventilator pressure-triggering?

a. Imposed WOB is less.
b. Trigger delay time is less.
c. Less trigger-work is required.
d. Required trigger pressure is less.
e. Mean peak inspiratory pressure is less.

[June 1996;41(6):512-518]

50. In the study by Emad, the outcome of adding alternate-day theophylline therapy to the routine treatment regimen of patients with moderate-to-severe asthma was what?

a. Spirometry values improved significantly.
b. β-2 agonist therapy could be discontinued.
c. Hospital admissions increased significantly.
d. Intermittent tremor was a common side effect.
e. Serum Theophylline exceeded therapeutic levels.

[June 1996;41(6):520-523]

Make sure to double check your work and to mark the answer sheet clearly. Mail your completed answer sheet by September 30, 1996 to

CRCE through the Journal
11030 Ables Lane
Dallas TX 75229-4593

Look for the answers in the October 1996 issue of RESPIRATORY CARE.

MEDWATCH

THE FDA MEDICAL PRODUCTS REPORTING PROGRAM

For VOLUNTARY reporting by health professionals of adverse events and product problems

Page ____ of ____

Form Approved OMB No. 0910-0291 Expires 4/30/96
See OMB statement on reverse

FDA Use Only (Resp Care)

Triage unit sequence #

A. Patient information

1. Patient identifier
In confidence

2 Age at time of event:
or
Date of birth:

3 Sex
☐ female
☐ male

4 Weight
____ lbs
or
____ kgs

B. Adverse event or product problem

1 ☐ Adverse event and/or ☐ Product problem (e g , defects/malfunctions)

2 Outcomes attributed to adverse event (check all that apply)
☐ death ____ (mo/day/yr)
☐ life-threatening
☐ hospitalization – initial or prolonged
☐ disability
☐ congenital anomaly
☐ required intervention to prevent permanent impairment/damage
☐ other

3. Date of event (mo/day/yr)

4 Date of this report (mo/day/yr)

5. Describe event or problem

6. Relevant tests/laboratory data, including dates

7 Other relevant history, including preexisting medical conditions (e g , allergies, race, pregnancy, smoking and alcohol use, hepatic/renal dysfunction, etc)

C. Suspect medication(s)

1 Name (give labeled strength & mfr/labeler, if known)
#1
#2

2 Dose, frequency & route used
#1
#2

3 Therapy dates (if unknown, give duration) (from to / or best estimate)
#1
#2

4 Diagnosis for use (indication)
#1
#2

5. Event abated after use stopped or dose reduced
#1 ☐ yes ☐ no ☐ doesn't apply
#2 ☐ yes ☐ no ☐ doesn't apply

6 Lot # (if known)
#1
#2

7 Exp. date (if known)
#1
#2

8 Event reappeared after reintroduction
#1 ☐ yes ☐ no ☐ doesn't apply
#2 ☐ yes ☐ no ☐ doesn't apply

9 NDC # (for product problems only)
– –

10. Concomitant medical products and therapy dates (exclude treatment of event)

D. Suspect medical device

1 Brand name

2. Type of device

3 Manufacturer name & address

4 Operator of device
☐ health professional
☐ lay user/patient
☐ other

5 Expiration date (mo/day/yr)

6.
model # ____
catalog # ____
serial # ____
lot # ____
other # ____

7 If implanted, give date (mo/day/yr)

8 If explanted, give date (mo/day/yr)

9 Device available for evaluation? (Do not send to FDA)
☐ yes ☐ no ☐ returned to manufacturer on ____ (mo/day/yr)

10. Concomitant medical products and therapy dates (exclude treatment of event)

E. Reporter (see confidentiality section on back)

1 Name & address

phone #

2. Health professional?
☐ yes ☐ no

3 Occupation

4 Also reported to
☐ manufacturer
☐ user facility
☐ distributor

5 If you do NOT want your identity disclosed to the manufacturer, place an " X " in this box. ☐

FDA

Mail to: MEDWATCH
5600 Fishers Lane
Rockville, MD 20852-9787

or FAX to:
1-800-FDA-0178

FDA Form 3500 1/96)

Submission of a report does not constitute an admission that medical personnel or the product caused or contributed to the event.

ADVICE ABOUT VOLUNTARY REPORTING

Report experiences with:

- medications (drugs or biologics)
- medical devices (including in-vitro diagnostics)
- special nutritional products (dietary supplements, medical foods, infant formulas)
- other products regulated by FDA

Report SERIOUS adverse events. An event is serious when the patient outcome is:

- death
- life-threatening (real risk of dying)
- hospitalization (initial or prolonged)
- disability (significant, persistent or permanent)
- congenital anomaly
- required intervention to prevent permanent impairment or damage

Report even if:

- you're not certain the product caused the event
- you don't have all the details

Report product problems – quality, performance or safety concerns such as:

- suspected contamination
- questionable stability
- defective components
- poor packaging or labeling
- therapeutic failures

How to report:

- just fill in the sections that apply to your report
- use section C for all products except medical devices
- attach additional blank pages if needed
- use a separate form for each patient
- report either to FDA or the manufacturer (or both)

Important numbers:

- 1-800-FDA-0178 to FAX report
- 1-800-FDA-7737 to report by modem
- 1-800-FDA-1088 to report by phone or for more information
- 1-800-822-7967 for a VAERS form for vaccines

If your report involves a serious adverse event with a device and it occurred in a facility outside a doctor's office, that facility may be legally required to report to FDA and/or the manufacturer. Please notify the person in that facility who would handle such reporting.

Confidentiality: The patient's identity is held in strict confidence by FDA and protected to the fullest extent of the law. The reporter's identity, including the identity of a self-reporter, may be shared with the manufacturer unless requested otherwise. However, FDA will not disclose the reporter's identity in response to a request from the public, pursuant to the Freedom of Information Act.

The public reporting burden for this collection of information has been estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to:

DHHS Reports Clearance Office
Paperwork Reduction Project (0910-0291)
Hubert H. Humphrey Building, Room 531-H
200 Independence Avenue, S.W.
Washington, DC 20201

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number.

Please do NOT return this form to either of these addresses.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service • Food and Drug Administration

FDA Form 3500-back

Please Use Address Provided Below – Just Fold In Thirds, Tape and Mail

Department of Health and Human Services
Public Health Service
Food and Drug Administration
Rockville, MD 20857

Official Business
Penalty for Private Use $300

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES OR APO/FPO

BUSINESS REPLY MAIL
FIRST CLASS MAIL PERMIT NO. 946 ROCKVILLE, MD

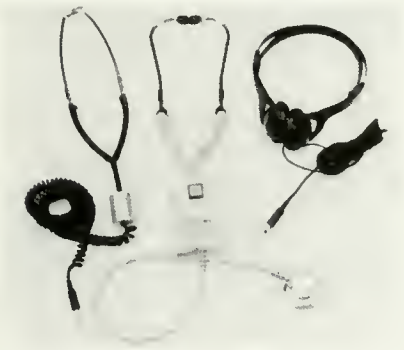
POSTAGE WILL BE PAID BY FOOD AND DRUG ADMINISTRATION

MEDWATCH
The FDA Medical Products Reporting Program
Food and Drug Administration
5600 Fishers Lane
Rockville, MD 20852-9787

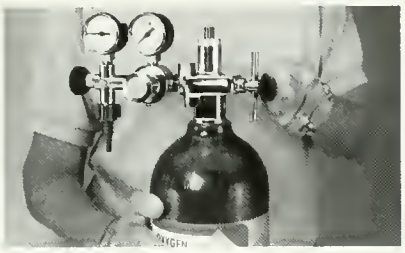
News releases about new products and services will be considered for publication in this section. There is no charge for these listings. Send descriptive release and glossy black and white photographs to RESPIRATORY CARE Journal, New Products and Services Dept, 11030 Ables Lane, Dallas TX 75229-4593.

New Products & Services

ASTHMA CARE KIT. HealthScan Products announces the AsthmaPACK: Personal Asthma Care Kit. According to HealthScan, the kit is a physician-directed, patient-managed asthma plan that contains the Personal Best® Peak Flow Meter with a daily record chart, OptiHaler® Clear MDI Drug Delivery System, the video tape, *Living with Asthma: What You Can Do*, and *Living With Asthma: What You Can Do—A Self-Help Booklet*. The kit allows patients to learn more about asthma episodes and triggers, the three-zone asthma management method, and the differences in nocturnal, exercise-induced, and occupational asthma. The package may be used for all ages in a variety of settings such as physician offices, pharmacies, emergency departments, and clinics. For more information about the AsthmaPACK, circle reader service card number 90.



ELECTRONIC STETHOSCOPE. Armstrong Medical Industries Inc releases the E-Scope™, an electronic stethoscope that amplifies heart, breath, or Korotkoff sounds. According to Armstrong, the E-Scope offers a sound-selector switch that allows the user to hear murmurs or faint sounds without enhancing background noise such as that encountered in ambulances, helicopters, emergency departments, or other noisy environments. The stethoscope can be attached to a tape recorder for audio reproduction of sounds to save for later comparison or analysis. Optional headphones provide enhanced amplification. Another option allows an instructor and student to listen simultaneously. Details are available from Armstrong. Circle reader service card number 91.



REGULATOR KEY. Victor Medical introduces the E-Z Key cylinder regulator key. The E-Z Key uses a standard cylinder wrench to tighten the regulator to the cylinder and prevents leaks with a simple twist, claims Victor Medical. The key is easy to use for patients and health-care providers. For details about the patent-pending key, circle number 92 on the reader service card.

REVALIDATION SERVICE. PDS—Pulmonary Data Service Instrumentation announces a Revalidation Service for 3-L calibration syringes used in pulmonary function testing. PDS suggests revalidation of syringes that have not been revalidated within the last year, have been dropped, or if the adjustable stopcock has been moved from the 3-L mark. According to PDS, the revalidation certification is traceable to the National Institute of Standards and Technology (NIST) and is provided at no charge. To learn more about PDS and this service, circle reader service card number 93.

WIRELESS CABLE. Mortara Instrument now offers a wireless patient cable, the X-12™. The cable provides real-time acquisition and transmission of simultaneous 12-lead electrocardiograph (ECG) data of diagnostic quality, claims the manufacturer. The X-12 is small (5″ × 2.5″), light weight, easy for health-care professionals and patients to use, and is pre-formed to ensure correct anatomical placement of electrodes. The cable requires 2 "AA" batteries for 30 hours of work. The cable can transmit on 256 channels. The cable is an available option for Mortara Instrument equipment: ELI 100 STM™, ELIXR/100®, ELIXR/200®, X-Scribe®, Portrait™ Resting & Stress, ELI 100® and ELI 200®. For information about the X-12, circle reader service card number 94.

PATIENT EDUCATION PAMPHLETS. Krames Communications offers patient education materials for respiratory care practitioners. *Chronic Obstructive Pulmonary Disease: Living with a Chronic Lung Condition*, *Asthma: Taking Control for a Healthier Life*, *Bronchoscopy*, and *Snoring and Sleep Apnea* are among the titles. According to Krames, each brochure is illustrated in full-color and is presented in an easy-to-read format. In addition, Krames offers safety, wellness, and employee-assistance education videos. For a catalog of the materials or for a free sample of a brochure or pamphlet, circle reader service card number 95.

RESPIRATORY CARE

Manuscript Preparation Guide

General Information

RESPIRATORY CARE welcomes original manuscripts related to respiratory care and prepared according to these Instructions. Manuscripts are blinded and reviewed by professionals who are experts in their fields. Authors are responsible for all aspects of the manuscript and receive galleys to proofread before publication. Each accepted manuscript is copyedited so that its message is clear and it conforms to the Journal's style. Published papers are copyrighted by Daedalus Inc and may not be published elsewhere without permission.

Editorial consultation is available at any stage of planning or writing. On request, specific guidance is provided for all publication categories. These Instructions and related materials are available. Write to RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593, call (214) 243-2272, or fax (214) 484-6010.

Publication Categories & Structure

Research Article: A report of an original investigation (a study). It includes a Title Page, Abstract, Introduction, Methods, Results, Discussion, Conclusions, Product Sources, Acknowledgments, References, Tables, Appendices, Figures, and Figure Captions.

Evaluation of Device/Method/Technique: A description and evaluation of an old or new device, method, technique, or modification. It has a Title Page, Abstract, Introduction, Description of Device/Method/Technique, Evaluation Methods, Evaluation Results, Discussion, Conclusions, Product Sources, Acknowledgments, References, Tables, Appendices, Figures, and Figure Captions.

Case Report: A report of a clinical case that is uncommon, or was managed in a new way, or is exceptionally instructive. All authors must be associated with the case. A case-managing physician must either be an author or furnish a letter approving the manuscript. Its components are Title Page, Abstract, Introduction, Case Summary, Discussion, References, Tables, Figures, and Figure Captions.

Review Article: A comprehensive, critical review of the literature and state-of-the-art summary of a pertinent topic that has been the subject of at least 40 published research articles. Title Page, Outline, Introduction, Review of the Literature, Summary, Acknowledgments, References, Tables, Appendices, and Figures and Captions may be included.

Overview: A critical review of a pertinent topic that has fewer than 40 published research articles.

Update: A report of subsequent developments in a topic that has been critically reviewed in this Journal or elsewhere.

Point-of-View Paper: A paper expressing personal but substantiated opinions on a pertinent topic. Title Page, Text, References, Tables, and Illustrations may be included.

Special Article: A pertinent paper not fitting one of the foregoing categories may be acceptable as a Special Article. Consult with the Editor before writing or submitting such a paper.

Editorial: A paper drawing attention to a pertinent concern; it may present an opposing opinion, clarify a position, or bring a problem into focus.

Letter: A signed communication about prior publications in this Journal or about other pertinent topics. Tables and illustrations may be included. Mark "For publication."

Blood Gas Corner: A brief, instructive case report involving blood-gas values—with Questions, Answers, and Discussion.

Drug Capsule: A mini-review paper about a drug or class of drugs that includes discussions of pharmacology, pharmacokinetics, and pharmacotherapy.

Kittredge's Corner: A brief description of the operation of respiratory care equipment—with information from manufacturers and editorial comments and suggestions.

PFT Corner: Like Blood Gas Corner, but involving pulmonary function tests.

Cardiorespiratory Interactions. A case report demonstrating the interaction between the cardiovascular and respiratory systems. It should be a patient-care scenario; however, the case—the central theme—is the systems interaction. CRI is characterized by figures, equations, and a glossary. See the March 1996 issue of RESPIRATORY CARE for more detail.

Test Your Radiologic Skill: Like Blood Gas Corner, but involving pulmonary medicine radiography and including one or more radiographs, may involve imaging techniques other than conventional chest radiography.

Review of Book, Film, Tape, or Software: A balanced, critical review of a recent release.

Preparing the Manuscript

Print on one side of white bond paper, 8.5 in. x 11 in. (216 x 279 mm) with margins of at least 1 in. (25 mm) on all sides of the page. Use ***double-spacing*** throughout the ***entire*** manuscript. Use a standard font (eg, Times, Helvetica, or Courier) at least 10 points in size, and do not use italics except for special emphasis. Number all pages in upper-right corners. Indent paragraphs 5 spaces. Do ***not justify***. Do ***not*** put authors' names or other identification anywhere except on the title page. Repeat title only (no authors) on the abstract page. Begin each of the following on a new page: Title Page, Abstract, Text, Product-Sources List, Acknowledgments, References, each Table, and each Appendix. Use standard English in the first person and active voice.

Center main section headings on the page and type them in capital and small letters (eg, Introduction, Methods, Results, Discussion). Begin subheadings at the left margin and type them in capital and small letters (eg, Patients, Equipment, Statistical Analysis).

References. Cite only published works as references. Manuscripts accepted but not yet published may be cited as references: designate the accepting journal, followed by (in press). Please provide 3 copies of the in-press article for reviewer inspection. Cite references in the text with superscript numerals. Assign numbers in the order that references are first cited. On the reference page, list the cited works in numerical order. Follow the Journal's style for references. Abbreviate journal names as in *Index Medicus*. List all authors.

Article in a journal carrying pagination throughout volume:

1. Rau JL, Harwood RJ. Comparison of nebulizer delivery methods through a neonatal endotracheal tube: a bench study. Respir Care 1992;37(11):1233-1240.

Article in a publication that numbers each issue beginning with Page 1:

2. Bunch D. Establishing a national database for home care. AARC Times 1991;15(Mar):61,62,64.

Corporate author journal article:

3. American Association for Respiratory Care. Criteria for establishing units for chronic ventilator-dependent patients in hospitals. Respir Care 1988;33(11):1044-1046.

Article in journal supplement: (Journals differ in their methods of numbering and identifying supplements. Supply sufficient information to promote retrieval.)

4. Reynolds HY. Idiopathic interstitial pulmonary fibrosis. Chest 1986;89(3, Suppl):139S-143S.

Abstract in journal: (Abstracts citations are to be avoided. Those more than 3 years old should not be cited.)

5. Stevens DP. Scavenging ribavirin from an oxygen hood to reduce environmental exposure (abstract). Respir Care 1990;35(11): 1087-1088.

Editorial in journal:

6. Enright P. Can we relax during spirometry? (editorial). Am Rev Respir Dis 1993;148(2):274.

Editorial with no author given:

7. Negative-pressure ventilation for chronic obstructive pulmonary disease (editorial). Lancet 1992;340(8833):1440-1441.

Letter in journal:

8. Aelony Y. Ethnic norms for pulmonary function tests (letter). Chest 1991;99(4):1051.

Paper accepted but not yet published:

9. Hess D. New therapies for asthma. Respir Care (year, in press).

Personal author book: (For any book, specific pages should be cited whenever possible.)

10. DeRemee RA. Clinical profiles of diffuse interstitial pulmonary disease. New York: Futura, 1990:76-85.

Corporate author book:

11. American Medical Association Department of Drugs. AMA drug evaluations, 3rd ed. Littleton CO: Publishing Sciences Group, 1977.

Chapter in book with editor(s):

12. Pierce AK. Acute respiratory failure. In: Guenter CA, Welch MH, editors. Pulmonary medicine. Philadelphia: JB Lippincott, 1977.

Tables. Use consecutively numbered tables to display information. Start each table on a separate page. Number and title the table and give each column a brief heading. Place explanations in footnotes, including all nonstandard abbreviations and symbols. Key the footnotes with conventional designations (asterisk, dagger, double dagger, etc) in consistent order, placing them superscript in the table body. Do not use horizontal or vertical rules or borders. Do not submit tables as photographs, reduced in size, or on oversize paper. Use the same typeface as in the text.

Illustrations. Graphs, line drawings, photographs, and radiographs are figures. Use only illustrations that clarify and augment the text. Number them consecutively as Fig. 1, Fig. 2, and so forth according to the order by which they are mentioned in the text. Be sure all figures are cited. If any figure was previously published, include copyright holder's written permission to reproduce. Figures for publication must be of professional quality. Data for the original graphs should be available to the Editor upon request. If color is essential, consult the Editor for more information. In reports of animal experiments, use schematic drawings, not photographs. A letter of consent must accompany any photograph of a person. Do not place titles and detailed explanations on figures; put this information in figure captions. If possible, submit radiographs as prints and full-size copies of film.

Drugs. Identify precisely all drugs and chemicals used, giving generic names, doses, and routes of administration. If desired, brand names may be given in parentheses after generic names. Drugs should be listed on the product-sources page.

Commercial Products. In parentheses in the text, identify any commercial product (including model number if applicable) the first time it is mentioned, giving the manufacturer's name, city, and state or country. If four or more products are mentioned, do not list any manufacturers in the text; instead, list them on a Product Sources page at the end of the text, before the References. Provide model numbers when available and manufacturer's suggested price, if the study has cost implications.

Ethics. When reporting experiments on human subjects, indicate that procedures were conducted in accordance with the ethical standards of the institution's committee on human experimentation. State that informed consent was obtained. Do not use patient's names, initials, or hospital numbers in text or illustrations. When reporting experiments on animals, indicate that the institution's policy, a national guideline, or a law on the care and use of laboratory animals was followed.

Statistics. Identify the statistical tests used in analyzing the data, and give the prospectively determined level of significance in the Methods section. Report actual p-values in Results. Cite only textbook and published article references to support choices of tests. Identify any general-use or commercial computer programs used, naming manufacturers and their locations. These should be listed on the product-sources page.

Units of Measurement. Express measurements of length, height, weight, and volume in metric units appropriately abbreviated; temperatures in degrees Celsius; and blood pressures in millimeters of mercury (mm Hg). Report hematologic and clinical-chemistry measurements in conventional metric and in SI (Systémé Internationale) units. Show gas pressures (including blood gas tensions) in torr. List SI equivalent values, when possible, in brackets following non-SI values—for example, "PEEP, 10 cm H_2O [0.981 kPa]." For conversion to SI, see RESPIRATORY CARE 1988;33(10):861-873 (Oct 1988) and 1989;34(2):145 (Feb 1989).

Conflict of Interest. Authors are asked to disclose any liaison or financial arrangement they have with a manufacturer or distributor whose product is part of the submitted manuscript or with the manufacturer or distributor of a competing product. (Such arrangements do not disqualify a paper from consideration and are not disclosed to reviewers.) A statement to this effect is included on the cover-letter page.

Abbreviations and Symbols. Use standard abbreviations and symbols. Avoid creating new abbreviations. Avoid all abbreviations in the title and unusual abbreviations in the abstract. Use an abbreviation only if the term occurs several times in the paper. Write out the full term the first time it appears, followed by the abbreviation in parentheses. Thereafter, employ the abbreviation alone. Never use an abbreviation without defining it. Standard units of measurement can be abbreviated without explanation (eg, 10 L/min, 15 torr, 2.3 kPa).

Please use the following forms: cm H_2O (not cmH2O), f (not bpm), L (not l), L/min (not LPM, l/min, or lpm), mL (not ml), mm Hg (not mmHg), pH (not Ph or PH), $p > 0.001$ (not p>0.001), s (not sec), S_{pO_2} (pulse-oximetry saturation).

Submitting the Manuscript

Mail three copies of the manuscript, figures, diskette, and the Cover Letter & Checklist to RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593. Do not fax manuscripts. Protect figures with cardboard. Keep a copy of the manuscript and figures. Receipt of your manuscript will be acknowledged.

Computer Diskettes. A manuscript may be submitted on a Macintosh or IBM-DOS diskette. Macintosh documents on 3.5 in. diskettes written in Microsoft Word versions 4.0 and 5.0 are preferred. However, we can convert most documents (including PC-DOS format) to our format. Label each diskette with date; author's name; name of word-processing program and version used to prepare documents; and filename(s). Do not write on a diskette except with a felt-tipped pen. Tables and figures must be in their own separate files, with software identified. Supply 3 hard copies of the manuscript with the diskette.

Prior and Duplicate Publication. Work that has been published or accepted elsewhere should not be submitted. In special instances, the Editor may consider such material, provided that permission to publish is given by the author and original publisher. Please consult the Editor before submitting such work.

Authorship. All persons listed as authors should have participated in the reported work and in the shaping of the manuscript; all must have proofread the submitted manuscript; and all should be able to publicly discuss and defend the paper's content. A paper with corporate authorship must specify the key persons responsible for the article. Authorship is not justified solely on the basis of solicitation of funding, collection or analysis of data, provision of advice, or similar services. Persons who provide such ancillary services exclusively may be recognized in an Acknowledgments section.

Permissions. The manuscript must be accompanied by copies of permissions to reproduce previously published material (figures or tables); to use illustrations of, or report sensitive personal information about, identifiable persons; and to name persons in the Acknowledgments section.

Reviewers. Please supply the names, credentials, affiliations, addresses, and phone/fax numbers of three professionals whom you consider expert on the topic of your paper. Your manuscript may be sent to one or more of them for blind peer review.

Editorial Office:

RESPIRATORY CARE
11030 Ables Lane
Dallas TX 75229-4593
(214) 243-2272 (telephone)
(214) 484-6010 (fax)

Cover Letter & Checklist

A copy of this completed form must accompany all manuscripts submitted for publication.

Title of Paper: _____

Publication Category: _____

Authors: _____

Author to be Contacted: _____ Phone: _____ FAX: _____

Mailing Address of Contact Author: _____

Reprints: ☐ Yes ☐ No

"We, the undersigned, have all participated in the work reported, proofread the accompanying manuscript, and approve its submission for publication." Please print and include credentials, title, institution, academic appointments, city and state. If more than 4 authors, please use another copy of this form.*

*Author Data: _____

Author Signature/Date _____

*Author Data: _____

Author Signature/Date _____

*Author Data: _____

Author Signature/Date _____

*Author Data: _____

Author Signature/Date _____

Has this research been presented in a public forum? ☐ Yes ☐ No

If yes, where, when and by whom? _____

Has this research received awards? ☐ Yes ☐ No

If yes, please describe. _____

Do any of the authors have a financial interest in the products mentioned in this paper or competing products?

☐ Yes ☐ No If yes, please disclose: _____

Checklist:

☐ Is double-spacing used throughout entire manuscript?
☐ Are all pages numbered in upper-right corners?
☐ Are all references, figures, and tables cited in the text?
☐ Has the accuracy of the references been checked, and are they correctly formatted?
☐ Have SI values been provided?
☐ Has all arithmetic been checked?
☐ Have generic names of drugs been provided?
☐ Have necessary written permissions been provided?
☐ Have authors' names been omitted from text and figure labels?
☐ Have copies of 'in press' references been provided?
☐ Has the manuscript been proofread by all the authors?

Notices

Notices of competitions, scholarships, fellowships, examination dates, new educational programs, and the like will be listed here free of charge. Items for the Notices section must reach the Journal 60 days before the desired month of publication (January 1 for the March issue, February 1 for the April issue, etc). Include all pertinent information and mail notices to RESPIRATORY CARE Notices Dept, 11030 Ables Lane, Dallas TX 75229-4593.

The National Board for Respiratory Care—1997 Examination Dates and Fees

Examination	Examination Date	Examination Fee	
CRTT Examination	March 8, 1997	$ 100	(new applicant)
	Application Deadline: January 1, 1997	60	(reapplicant)
	July 12, 1997	100	(new applicant)
	Application Deadline: May 1, 1997	60	(reapplicant)
	November 8, 1997	100	(new applicant)
	Application Deadline: September 1, 1997	60	(reapplicant)
RRT Examination	June 7, 1997	100	Written only (new applicant)
	Application Deadline: February 1, 1997	60	Written only (reapplicant)
		110	CSE only (all applicants)
	December 6, 1997	210	Both (new applicant)
	Application Deadline: August 1, 1997	170	Both (reapplicant)
CPFT Examination	June 7, 1997	110	(new applicant)
	Application Deadline: April 1, 1997	80	(reapplicant)
RPFT Examination	December 6, 1997	160	(new applicant)
	Application Deadline: September 1, 1997	130	(reapplicant)
Perinatal/Pediatric Respiratory Care Specialty Examination	March 8, 1997	160	(new applicant)
	Application Deadline: November 1, 1996	130	(reapplicant)

For information about other services or fees, write to the National Board for Respiratory Care, 8310 Nieman Road, Lenexa KS 66214, or call (913) 599-4200, FAX (913) 541-0156, email nbrc-info@nbrc.org.

Web Site for Tuberculosis Information

The University of Medicine & Dentistry of New Jersey has established a world wide web site for information about tuberculosis (TB). The site, one of 3 model tuberculosis prevention, control, and education centers established by the Centers for Disease Control and Prevention, provides technical medical material for health-care providers and general information for the public. Current information about TB epidemiology, transmission, diagnosis, and treatment, as well as education and training schedules and course descriptions are available. The web sites address is

http://www.umdnj.edu/ntbc.

The center also operates a toll-free information line at (800) 4TB - DOCS

American Association for Respiratory Care Membership Application

Please read the eligibility requirements for each of the classifications in the right-hand column, then complete the applicable section. All information requested below must be provided, except where indicated as optional. See other side for more information and fee schedule. Please sign and date application on reverse side and type or print clearly. Processing of application takes approximately 15 days.

- ☐ Active
- Associate
  - ☐ Foreign
  - ☐ Physician
  - ☐ Industrial
- ☐ Special
- ☐ Student

Last Name _____

First Name _____ Middle _____

Social Security No. _____

Home Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

Primary Job Responsibility (check one only)

- ☐ Technical Director
- ☐ Assistant Technical Director
- ☐ Pulmonary Function Specialist
- ☐ Instructor/Educator
- ☐ Supervisor
- ☐ Staff Therapist
- ☐ Staff Technician
- ☐ Rehabilitation/Home Care
- ☐ Medical Director
- ☐ Sales
- ☐ Student
- ☐ Other, specify _____

Type of Business

- ☐ Hospital
- ☐ Skilled Nursing Facility
- ☐ DME/HME
- ☐ Home Health Agency
- ☐ Educational Institution
- ☐ Manufacturer or supplier
- ☐ Other, specify _____

Date of Birth (optional) _____ Sex (optional) _____

U.S. Citizen? ___ Yes ___ No

Have you ever been a member of the AARC? _____

If so, when? From _____ to _____

Preferred mailing address: ☐ Home ☐ Business

FOR ACTIVE MEMBER

An individual is eligible if he/she lives in the U.S. or its territories or was an Active Member prior to moving outside its borders or territories, and meets ONE of the following criteria: (1) is legally credentialed as a respiratory care professional if employed in a state that mandates such, OR (2) is a graduate of an accredited educational program in respiratory care, OR (3) holds a credential issued by the NBRC. An individual who is an AARC Active Member in good standing on December 8, 1994 will continue as such provided his/her membership remains in good standing

Place of Employment _____

_____

Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

Medical Director/Medical Sponsor _____

FOR ASSOCIATE OR SPECIAL MEMBER

Individuals who hold a position related to respiratory care but do not meet the requirements of Active Member shall be Associate Members. They have all of the rights and benefits of the Association except to hold office, vote, or serve as chair of a standing committee. The following subclasses of Associate Membership are available: Foreign, Physician, and Industrial (individuals whose primary occupation is directly or indirectly devoted to the manufacture, sale, or distribution of respiratory care equipment or supplies) Special Members are those not working in a respiratory care-related field

PLEASE USE THE ADDRESS OF THE LOCATION WHERE YOU PERFORM YOUR JOB, NOT THE CORPORATE HEADQUARTERS IF IT IS LOCATED ELSEWHERE.

Place of Employment _____

_____

Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

FOR STUDENT MEMBER

Individuals will be classified as Student Members if they meet all the requirements for Associate Membership and are enrolled in an educational program in respiratory care accredited by, or in the process of seeking accreditation from, an AARC-recognized agency

SPECIAL NOTICE — Student Members do not receive Continuing Respiratory Care Education (CRCE) transcripts. Upon completion of your respiratory care education, continuing education credits may be pursued upon your reclassification to Active or Associate Member.

School/RC Program _____

_____

Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

Length of Program

☐ 1 year ☐ 4 years

☐ 2 years ☐ Other, specify_____

Expected Date of Graduation (REQUIRED INFORMATION)

Month_____ Year_____

American Association for Respiratory Care • 11030 Ables Lane • Dallas, TX 75229-4593 • (214) 243-2272 • FAX (214) 484-2720

American Association for Respiratory Care Membership Application

Demographic Questions

We request that you answer these questions in order to help us design services and programs to meet your needs.

Check the Highest Degree Earned

- ☐ High School
- ☐ RC Graduate Technician
- ☐ Associate Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctorate Degree

Number of Years in Respiratory Care

- ☐ 0-2 years
- ☐ 3-5 years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ 16 years or more

Job Status

- ☐ Full Time
- ☐ Part Time

Credentials

- ☐ RRT
- ☐ CRTT
- ☐ Physician
- ☐ CRNA
- ☐ RN
- ☐ LVN/LPN
- ☐ CPFT
- ☐ RPFT
- ☐ Perinatal/Pediatric

Salary

- ☐ Less than $10,000
- ☐ $10,001-$20,000
- ☐ $20,001-$30,000
- ☐ $30,001-$40,000
- ☐ $40,001 or more

PLEASE SIGN

I hereby apply for membership in the American Association for Respiratory Care and have enclosed my dues. If approved for membership in the AARC, I will abide by its bylaws and professional code of ethics. I authorize investigation of all statements contained herein and understand that misrepresentations or omissions of facts called for is cause for rejection or expulsion.

A yearly subscription to **Respiratory Care** journal and **AARC Times** magazine includes an allocation of $6.50 from my dues for each of these publications.

NOTE: Contributions or gifts to the AARC are not tax deductible as charitable contributions for income tax purposes. However, they may be tax deductible as ordinary and necessary business expenses subject to restrictions imposed as a result of association lobbying activities. The AARC estimates that the nondeductible portion of your dues - the portion which is allocable to lobbying - is 26%.

Signature _____

Date _____

Membership Fees

Payment must accompany your application to the AARC. Fees are for 12 months. (NOTE: Renewal fees are $65.00 Active, Associate-Industrial or Associate-Physician, or Special status; $80.00 for Associate-Foreign status; and $35.00 for Student status.)

☐ Active	$77.50
☐ Associate (Industrial or Physician)	$77.50
☐ Associate (Foreign)	$92.50
☐ Special	$77.50
☐ Student	$35.00
TOTAL	$_____

Specialty Sections

Established to recognize the specialty areas of respiratory care. The sections publish a newsletter four times a year that focuses on issues of specific concern to that specialty. The sections also design the specialty programming at the national AARC meetings.

☐ Adult Acute Care Section	$ 5.00
☐ Education Section	$10.00
☐ Perinatal-Pediatric Section	$ 5.00
☐ Diagnostics Section	$ 5.00
☐ Continuing Care-Rehabilitation Section	$ 5.00
☐ Management Section	$10.00
☐ Transport Section	$ 5.00
☐ Home Care	$ 5.00
☐ Subacute Care	$ 5.00
TOTAL	$_____

GRAND TOTAL = Membership Fee plus optional sections $_____

☐ Total Amount Enclosed $_____

☐ Please charge my dues (see below)

To charge your dues, complete the following:

- ☐ MasterCard
- ☐ Visa

Card Number

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Card Expires _____/_____

Signature _____

Mail Application and Appropriate Fees To:

American Association for Respiratory Care • 11030 Ables Lane • Dallas • TX 75229-4593 • (214) 243-2272 • FAX (214) 484-2720

Not-for-profit organizations are offered a free advertisement of up to eight lines to appear, on a space-available basis, in Calendar of Events in RESPIRATORY CARE. Ads for other meetings are priced at $5.50 per line and require an insertion order. Deadline is the 20th of the month two months preceding the month in which you wish the ad to run. Submit copy and insertion orders to Calendar of Events, RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593.

Calendar of Events

AARC & AFFILIATES

August 14–16—Mexican Association
4th International Congress at the World Trade Center, Mexico City, Mexico. Contact: Dr Hector Leon Garza at 011-525-578-0769, fax 011-525-578-8952. To receive an application for room reservations near the World Trade Center, contact the Fundacion Turistica Cesar Ritz at 011-525-207-2414, fax 011-525-574-1058.

August 27—AARC Video Conference
"Theory and Application of Neonatal Ventilation: What, When, and Why," Part 5 of the 1996, 7-part video conference "Professor's Rounds in Respiratory Care," from 12:30 to 2 p.m. Eastern Time. Live telephone question-and-answer session airs Sept. 16. CRCE: 1 credit hour. Contact: AARC at (214) 243-2272.

September 5–6—Chapter 10 of the California Society
Together with the American Lung Association of the Redwood Empire, & Napa Valley College of Respiratory Therapy Program present the 14th Annual Napa Valley Conference: Current Concepts in Cardiopulmonary Care in Napa, California. Contact: Kate Benscoter at (707) 253-3145.

September 11–13—The Maryland/District of Columbia Society for Respiratory Care
15th Annual Conference by the Sea at the Carousel Hotel in Ocean City, Maryland. Contact: Jacqueline Smith at (703) 719-3916 or Elgloria Harrison at (202) 547-6817.

October 2–4—Kentucky Society
Annual State Meeting, "Strive for Excellence," at the Hurstborne Conference Center in Louisville, Kentucky. Contact: Janet Vogt at (502) 562-3002.

October 11—Southern Chapter of the Colorado Society
3rd Annual Southern Colorado Pulmonary Medicine Symposium at the Holiday Inn Garden of the Gods in Colorado Springs, Colorado. Lunch is included in the $15 fee. Contact: Barry Beard at (719) 776-5211, fax (719) 776-2535.

OTHER MEETINGS

September 12–13—University of Nebraska at Lincoln
6th Annual Lincoln Pulmonary Conference: Pulmonary Care Beyond 2000 in Lincoln, Nebraska. Contact: The University of Nebraska–Lincoln, Division of Continuing Studies, at (402) 472-2844, fax (402) 472-9688.

September 26–27—INFOCARE
First Annual Neonatal/Pediatric Respiratory/Critical Care Symposium at the Sheraton Beach Resort in South Padre Island, Texas. Contact: INFOCARE, 350 San Roman Rd, Los Fresnos TX 78566, (210) 233-5645.

October 4–6—American Lung Association of Western Missouri
Ozark Chest Conference XVI, "Current Issues in Pulmonary Medicine," at the Tan Tara Resort, Osage Beach, Missouri. Contact: Becky Martin, 2007 Broadway, Kansas City MO 64108, (816) 842-5242, fax (816) 842-5470.

October 19–20—Kansas Association of Cardiovascular and Pulmonary Rehabilitation
9th Annual Meeting, "Cardiac and Pulmonary Rehabilitation: Prevention and Treatment," at the Holiday Inn Crowne Plaza, Kansas City, Missouri. Contact: Mary Cullen, Research Medical Center, 2316 E Meyer Blvd, Kansas City MO 64132, (816) 276-3984.

November 9—North Central Florida Post-Polio Support Group
"Post-Polio Syndrome: It Can Take Your Breath Away," in Ocala, Florida. Contact: Carolyn Raville, 7180 SW 182nd Ct, Dunnellon FL 34432, (352) 489-1731.

March 5–7, 1997—Journées Internationales de Ventilation à Domicile (JIVD)
6th International Conference on Home Mechanical Ventilation, in Lyon, France. The official languages of the conference are English and French; simultaneous translation will be provided. Abstracts are due by Dec. 15. For guidelines on abstract submissions and for more information on the conference, contact the Congress Secretariat at JIVD, Hôpital de la Croix Rousse, Service de Réanimation Médicale et Assistance Respiratoire, 93 Grande Rue de la Croix Rousse, 69317 Lyon Cedex 04, France, or call (33) 78 39 08 43, fax (33) 78 39 58 63, or send E-mail to 100732.3540@compuserve.com.

Authors in This Issue

Branson, Richard D 736
Brown, Bruce 750
Brudno, D Spencer 724
Chan, Edward 735
Chatburn, Robert L 728
Comroe Jr, Julius H 752
Davis Jr, Kenneth 736
Dennison, Frank 724
Douce, F Herbert 755
Dunlevy, Crystal L 755
Eagleton, Lanie E 703
El-Khatib, Mohamad 728
England, Kevin R 703
Fraser, Jeff 750
Giordano, Sam P 750
Henkle, Joseph Q 703
Hoberty, Phillip D 748, 755
Knauf, Jared 748
Kremenchugsky, Vladimir 724
Lain, David 724
Op't Holt, Timothy B 714
Scaggs, John E 703
Shrake, Kevin L 703
Veatch, Matthew 745
Volsko, Teresa A 728
Wanger, Jack 745

Advertisers in This Issue

To advertise in RESPIRATORY CARE, contact Tim Goldsbury, 20 Tradewinds Circle, Tequesta FL 33469 at (407) 745-6793, Fax (407) 745-6795, email: timo2 6907@aol.com, for rates and media kits. For recruitment/classified advertising contact RESPIRATORY CARE's Marketing Assistant, Beth Binkley, at (214)243-2272, Fax (214)484-6010. Dale Griffiths is RESPIRATORY CARE's Marketing Director.

California College for Health Sciences 691
Circle Reader Service No. 99 Call (800) 221-7374

HealthScan Products Inc ..... Cover 3
Circle Reader Service No. 119 Call (800) 962-1266

NovaMetrix Medical Systems Inc ..... Cover 2
Circle Reader Service No. 109 Call (800) 243-3444

Sherwood Medical ..... Cover 4
Circle Reader Service No. 104 Call (800) 325-7472

COPYRIGHT INFORMATION. RESPIRATORY CARE is copyrighted by Daedalus Enterprises Inc. Reproduction in whole or in part without the express written permission of Daedalus Enterprises Inc is prohibited. Permission to photocopy material in this Journal for noncommercial purposes of scientific or educational advancement is granted. Anyone may, without permission, quote up to 500 words of material in this journal provided the quotation is for noncommercial use and RESPIRATORY CARE is credited. Longer quotation requires written approval by the author and publisher. Single reprints are available only from the authors. Reprints for commercial use may be purchased from Daedalus Enterprises Inc. For information and prices call (214) 243-2272.

DISCLAIMER. The opinions expressed in any article or editorial are those of the author and do not necessarily reflect the views of the Editors, the American Association for Respiratory Care (AARC), or Daedalus Enterprises Inc. Neither are the Editors, the AARC or the Publisher responsible for the consequences of the clinical applications or use of any methods or devices described in any article or advertisement.

SUBSCRIPTION RATES. Individual subscription rates are $65 per year (12 issues), $125 for 2 years, and $185 for 3 years in the US and Puerto Rico. Rates are $80 per year, $155 for 2 years, and $230 for 3 years in all other countries (add $84 per year for air mail). Single copies when available cost $5; add $7 for air mail postage to overseas countries. Checks should be made payable to RESPIRATORY CARE and sent to the subscription office at 11030 Ables Lane, Dallas TX 75229-4593.

SUBSCRIPTION RATES FOR ASSOCIATIONS. An association may offer individual subscriptions of RESPIRATORY CARE to its members at a reduced rate. The rates based on membership are: $6 per year for 101-500 members; $5.50 for 501-1,500 members; $5 for 1,501-10,000 members; $4 for more than 10,000 members. For information, contact Ray Masferrer at (214) 243-2272.

CHANGE OF ADDRESS. Notify RESPIRATORY CARE as soon as possible of any change in address. Note the subscription number (from the mailing label) and your name, old address, and new address. Allow 6 weeks for the change. To avoid charges for replacement copies of missed issues, requests must be made within 60 days in the US and 90 days in other countries.

MANUSCRIPTS. The Journal publishes clinical studies, method/device evaluations, reviews, and other materials related to cardiopulmonary medicine and research. Manuscripts may be submitted to the Editorial Office, RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593. Instructions for authors are printed in every issue. An expanded version of the Instructions is available from the editorial office.

Copyright © 1996, by Daedalus Enterprises Inc.

RESPIRATORY CARE

August 1996 Reader Service Reply Card **Expires 11/30/96**

Name _____ Phone _____

Institution _____

Street _____

City/State/Zip _____

For faster service, FAX to (609) 786-4415

Send Free Information on the Items Circled Below
(Please Circle No More Than 15 Items)

80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
110	111	112	113	114	115	116	117	118	119	120	121	122	123	124
125	126	127	128	129	130	131	132	133	134	135	136	137	138	139
140	141	142	143	144	145	146	147	148	149	150	151	152	153	154
155	156	157	158	159	160	161	162	163	164	165	166	167	168	169
170	171	172	173	174	175	176	177	178	179	180	181	182	183	184
185	186	187	188	189	190	191	192	193	194	195	196	197	198	199

For AARC Membership Information, Circle 81.
For RESPIRATORY CARE Subscription Information, Circle 82.

I. Type of Institution/Practice
1. ❑ Hosp 500 or more beds
2. ❑ Hosp 300 to 499 beds
3. ❑ Hosp 200 to 299 beds
4. ❑ Hosp 100 to 199 beds
5. ❑ Hosp 100 or less beds
6. ❑ Skilled Nursing Facility
7. ❑ Home Care Practice
8. ❑ School

II. Department
A. ❑ Respiratory Therapy
B. ❑ Cardiopulmonary
C. ❑ Anesthesia Service
D. ❑ Emergency Dept

III. Specialty
1. ❑ Clinical Practice
2. ❑ Perinatal Pediatrics
3. ❑ Critical Care
4. ❑ Clinical Research
5. ❑ Pulmonary Function Lab
6. ❑ Home Care/Rehab
7. ❑ Education
8. ❑ Management

IV.Position
A. ❑ Dept Head
B. ❑ Chief Therapist
C. ❑ Supervisor
D. ❑ Staff Technician
E. ❑ Staff Therapist
F. ❑ Educator
G. ❑ Medical Director
H. ❑ Anesthesiologist
I. ❑ Pulmonologist
J. ❑ Other MD
K. ❑ Nurse

V. Are you a member of the AARC?
1. ❑ Yes 2. ❑ No

RESPIRATORY CARE

August 1996 Reader Service Reply Card **Expires 11/30/96**

Name _____ Phone _____

Institution _____

Street _____

City/State/Zip _____

For faster service, FAX to (609) 786-4415

Send Free Information on the Items Circled Below
(Please Circle No More Than 15 Items)

80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
110	111	112	113	114	115	116	117	118	119	120	121	122	123	124
125	126	127	128	129	130	131	132	133	134	135	136	137	138	139
140	141	142	143	144	145	146	147	148	149	150	151	152	153	154
155	156	157	158	159	160	161	162	163	164	165	166	167	168	169
170	171	172	173	174	175	176	177	178	179	180	181	182	183	184
185	186	187	188	189	190	191	192	193	194	195	196	197	198	199

For AARC Membership Information, Circle 81.
For RESPIRATORY CARE Subscription Information, Circle 82.

I. Type of Institution/Practice
1. ❑ Hosp 500 or more beds
2. ❑ Hosp 300 to 499 beds
3. ❑ Hosp 200 to 299 beds
4. ❑ Hosp 100 to 199 beds
5. ❑ Hosp 100 or less beds
6. ❑ Skilled Nursing Facility
7. ❑ Home Care Practice
8. ❑ School

II. Department
A. ❑ Respiratory Therapy
B. ❑ Cardiopulmonary
C. ❑ Anesthesia Service
D. ❑ Emergency Dept

III. Specialty
1. ❑ Clinical Practice
2. ❑ Perinatal Pediatrics
3. ❑ Critical Care
4. ❑ Clinical Research
5. ❑ Pulmonary Function Lab
6. ❑ Home Care/Rehab
7. ❑ Education
8. ❑ Management

IV.Position
A. ❑ Dept Head
B. ❑ Chief Therapist
C. ❑ Supervisor
D. ❑ Staff Technician
E. ❑ Staff Therapist
F. ❑ Educator
G. ❑ Medical Director
H. ❑ Anesthesiologist
I. ❑ Pulmonologist
J. ❑ Other MD
K. ❑ Nurse

V. Are you a member of the AARC?
1. ❑ Yes 2. ❑ No

I attest that I completed the Answer Sheet independently, without help from others.

_____ Signature

_____ Date

Authors in This Is

Branson, Richard D..
Brown, Bruce.....
Brudno, D Spencer....
Chan, Edward.....
Chatburn, Robert L....
Comroe Jr, Julius H..
Davis Jr, Kenneth.....
Dennison, Frank.....
Douce, F Herbert.....
Dunlevy, Crystal L....
Eagleton, Lanie E.....
El-Khatib, Mohamad
England, Kevin R.....

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST-CLASS MAIL PERMIT NO. 439 RIVERTON, NJ

POSTAGE WILL BE PAID BY ADDRESSEE

AARC Publications
PO BOX 11605
RIVERTON NJ 08076-7205

Advertise in This Is

California College for
Circle Reader Service N
HealthScan Products
Circle Reader Service N

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST-CLASS MAIL PERMIT NO. 439 RIVERTON, NJ

POSTAGE WILL BE PAID BY ADDRESSEE

AARC Publications
PO BOX 11605
RIVERTON NJ 08076-7205

COPYRIGHT INFORMA
Daedalus Enterprises In
express written permiss
Permission to photocopy
poses of scientific or ed
without permission, quo
vided the quotation is fo
credited. Longer quotat
publisher. Single reprint
commercial use may be
information and prices call (214) 243-2272.

DISCLAIMER. The opinions expressed in any article or editorial are those of the author and do not necessarily reflect the views of the Editors, the American Association for Respiratory Care (AARC), or Daedalus Enterprises Inc. Neither are the Editors, the AARC or the Publisher responsible for the consequences of the clinical applications or use of any methods or devices described in any article or advertisement.

SUBSCRIPTION RATES. Individual subscription rates are $65 per year (12 issues), $125 for 2 years, and $185 for 3 years in the US and Puerto Rico. Rates are $80 per year, $155 for 2 years, and $230 for 3 years in all other countries (add $84 per year for air mail). Single copies when available cost $5; add $7 for air mail postage to overseas countries. Checks should be

CHANGE OF ADDRESS. Notify RESPIRATORY CARE as soon as possible of any change in address. Note the subscription number (from the mailing label) and your name, old address, and new address. Allow 6 weeks for the change. To avoid charges for replacement copies of missed issues, requests must be made within 60 days in the US and 90 days in other countries.

MANUSCRIPTS. The Journal publishes clinical studies, method/device evaluations, reviews, and other materials related to cardiopulmonary medicine and research. Manuscripts may be submitted to the Editorial Office, RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593. Instructions for authors are printed in every issue. An expanded version of the Instructions is available from the editorial office.

Copyright © 1996, by Daedalus Enterprises Inc.

RESPIRATORY CARE

We are pleased to offer ***CRCE through the Journal*** for 1996. On the other side of this page, you will find grids for your name, AARC member number, and answers to the questions. Complete the grids by using these rules:

Only original Answer Sheets will be graded. (This page is perforated to make it easy to complete and mail.) No facsimiles or photocopies will be accepted. Six hours of CRCE credit is awarded to those who answer 35 or more questions correctly.

You may photocopy the Answer Sheet for your personal record. The Answer Key will be published in the October issue of RESPIRATORY CARE.

Obtain a check or money order for $5 payable to AARC. (This is for processing; your Answer Sheet will not be graded if the fee is not included.)

Read and sign the statement below.

Place the Original Answer Sheet and processing fee in a stamped #10 envelope and mail to:

CRCE through the Journal
11030 Ables Lane
Dallas TX 75229-4593

Deadline is September 30, 1996. Responses postmarked after September 30, 1996 will not be processed.

Follow all instructions explicitly. Failure to do so may cause technical problems that could disqualify you.

Questions relating to completing the examination should be directed to the CRCE Coordinator, (214) 243-2272.

I attest that I completed the Answer Sheet independently, without help from others.

_____ _____

Signature Date

CRCE through the Journal — Answer Sheet

See the bottom of this page for instructions on marking this form.

	a	b	c	d	e
1	○	○	○	○	○
2	○	○	○	○	○
3	○	○	○	○	○
4	○	○	○	○	○
5	○	○	○	○	○
6	○	○	○	○	○
7	○	○	○	○	○
8	○	○	○	○	○
9	○	○	○	○	○
10	○	○	○	○	○
11	○	○	○	○	○
12	○	○	○	○	○
13	○	○	○	○	○
14	○	○	○	○	○
15	○	○	○	○	○
16	○	○	○	○	○
17	○	○	○	○	○
18	○	○	○	○	○
19	○	○	○	○	○
20	○	○	○	○	○
21	○	○	○	○	○
22	○	○	○	○	○
23	○	○	○	○	○
24	○	○	○	○	○
25	○	○	○	○	○
26	○	○	○	○	○
27	○	○	○	○	○
28	○	○	○	○	○
29	○	○	○	○	○
30	○	○	○	○	○
31	○	○	○	○	○
32	○	○	○	○	○
33	○	○	○	○	○
34	○	○	○	○	○
35	○	○	○	○	○
36	○	○	○	○	○
37	○	○	○	○	○
38	○	○	○	○	○
39	○	○	○	○	○
40	○	○	○	○	○
41	○	○	○	○	○
42	○	○	○	○	○
43	○	○	○	○	○
44	○	○	○	○	○
45	○	○	○	○	○
46	○	○	○	○	○
47	○	○	○	○	○
48	○	○	○	○	○
49	○	○	○	○	○
50	○	○	○	○	○

Please print your name and AARC member number exactly as it appears on the mailing label and carefully fill in the corresponding circles below.

Member Name:

	LAST										FIRST							MI
A	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
B	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
C	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
D	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
E	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
F	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
G	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
H	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
I	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
J	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
K	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
M	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
N	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
O	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
P	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Q	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
R	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
S	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
T	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
U	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
V	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
W	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
X	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Y	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Z	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Second Fold Here

AARC Member Number:

0	○	○	○	○	○	○	○
1	○	○	○	○	○	○	○
2	○	○	○	○	○	○	○
3	○	○	○	○	○	○	○
4	○	○	○	○	○	○	○
5	○	○	○	○	○	○	○
6	○	○	○	○	○	○	○
7	○	○	○	○	○	○	○
8	○	○	○	○	○	○	○
9	○	○	○	○	○	○	○

For office use only

Total correct ____

Percent correct ____

☐ Pass ☐ Fail

First Fold Here

Tips to ensure accurate grading and proper credit:

- Use only a #2, **soft-lead** pencil.
- Mark only **one answer**.
- If you must change your answer, **erase completely**.
- Make dark marks and **fill the circle** completely.

Examples

Do make your marks like this: ○ ○ ● ○ ○

Do Not make marks like this: ○ ✓ ○ ○ ○

Do Not make marks like this: ○ ○ ○ ✗ ○

OptiHaler®
CLEAR
Drug Delivery System

Now! See the Difference

OptiHaler® — the innovative drug delivery system for use with metered dose inhalers — is now clear and made of impact-resistant polycarbonate.

See the difference.

OptiHaler® Clear allows you to see how it improves drug delivery. Witness its *dynamic mixing action*.

Coordinates inhalation with medication release.

With OptiHaler, proper MDI technique is easy. Patients begin breathing in and then actuate their canisters. *OptiHaler does the rest.*

OptiHaler encourages correct MDI technique for consistent drug delivery, every time. It helps eliminate the problems patients have with timing.

OptiHaler's unique design limits the patient's air intake until the MDI is depressed...coordinating actuation of the canister with the beginning of inhalation.

Convenience promotes compliance.

OptiHaler's "difference" allows it to be smaller, more portable and as effective as conventional spacers and holding chambers.[1]

Although it's small, patients can store their MDI canisters inside, making OptiHaler truly portable and convenient in comparison to ordinary spacers and holding chambers.

Convenience promotes compliance — your patients will use OptiHaler. And it's dishwasher-safe, for easy effective cleaning.

Easy to Use: Breathe In and Press Down

For more information or the name of a HealthScan Distributor near you, call:

1-800-962-1266

HEALTHSCAN PRODUCTS INC. a division of HEALTHDYNE TECHNOLOGIES

©1996, HealthScan Products Inc. OP0296-0

REFERENCES 1. Data on file, HealthScan Products Inc.

Circle 119 on reader service card

INTRODUCING

3 NEW Technologies in Arterial Blood Sampling

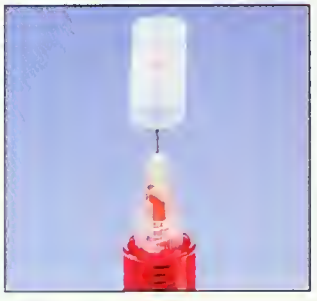
ASPIR-PULSE™ Arterial Blood Gas System

NEW, Advanced ***ASPIR-PULSE***™ Syringe

Patented design improves filling for both **Aspir**ation and ***Puls***ation techniques

NEW, Purge Guard™
One-Handed Safety Needle Venting System

Patent-pending design allows One-Handed operation to immediately **Purge** Air Bubbles, immediately **Guard** the needle point and immediately free the other hand to apply pressure at the puncture site



NEW, Total Ca++ Lyte™
Precision Heparin

A breakthrough patented heparin to maximize the precision of test results obtained from the new critical-care blood gas and critical analyte analyzers

	Non-Heparinized Control	Aspir-Pulse™ Total Ca++ Lyte
pH	1.22¹ 1.24¹	1.23¹
pCO2	2.38¹	2.35¹
pO2	0	12¹

See your Sherwood Medical O.R./Critical Care Sales Representative or call 1-800-325-7472 for a complete listing of ***ASPIR-Pulse***™ Arterial Blood Gas Kits.

Sherwood MEDICAL
ST LOUIS, MO 63103 U.S.A.

Circle 104 on reader service card

Sherwood Medical Company